ISSN (Print) : 2467-9291
ISSN (Online) : 2467-9305

Journal of Maize Research and Development

Vol. 1, No. 1, December 2015

Government of Nepal
Nepal Agricultural Research Council
National Maize Research Program
Rampur, Chitwan, Nepal

ISSN (Print): 2467-9291
ISSN (Online): 2467-9305

Journal of Maize Research and Development

Vol. 1, No. 1, December 2015

Government of Nepal
Nepal Agricultural Research Council
National Maize Research Program
Rampur, Chitwan, Nepal

Journal of Maize Research and Development (2015) 1(1)

www.nmrp.gov.np

General Information: Journal of Maize Research and Development (JMRD) is dedicated to publishing high-quality original research and review articles on maize breeding, genetics, agronomy, entomology, pathology, post harvest, soil science, botany, physiology, conservation agriculture and climate change effect on maize, maize economics, up-scaling research on maize and plant biotechnological approaches for maize improvement. The main objective of JMRD is to serve as a platform for the international scholars, academicians, researchers, and extensonists to share the innovative research findings in maize. The JMRD is an online open access international, peer reviewed and official journal published annually in month of December by National Maize Research Program, Rampur, Chitwan, Nepal.

Abstracting and Indexing:
JMRD is abstracted in Google Scholar, Pak Academic Search, Research Gate, Mendeley, Academia.edu, ResearchBib, Open Acess Library, NARC Library, World Cat, World Catalogue of Science Journals, CiteUlike, MIAR 2015 Live, IFSIJ, Scientific indexing service (SIS), Gaudeamus, Advanced Sciences Index (ASI), Eurasian Scientific Journal Index (ESJI), The Open Directory, ISSUU etc.

Welcome Message from the NMRP Coordinator

Dear All,

It is our great pleasure to share with you the inaugural issue of ***Journal of Maize Research and Development (JMRD)***, a new open access journal is going to be published by National Maize Research Program Rampur Chitwan Nepal on December, 2015. JMRD is dedicated to the rapid dissemination of high-quality original research and review articles on maize breeding, genetics, agronomy, entomology, pathology, post harvest, soil science, botany, physiology, conservation agriculture and climate change effect on maize, maize economics, up-scaling research on maize and plant biotechnological approaches for maize improvement and promotion. Our aim is to serve as a platform for the international scholars, academicians, researchers, and extensionists to share the innovative research findings and key development issue in maize.

It is my expectation that this journal provides a real ideal forum for exchange of information on maize research achievements at national and international level. It provides useful information to all maize researchers, scientist, extensionists and academicians in the field of maize research and development. I am elated to thank our authors, editors and reviewers, all of whom have volunteered to contribute to the success of the journal. I am very much grateful to Scientist Jiban Shrestha, our Senior Scientist Tika Bahadur Karki and Scientist Subash Subedi at NMRP, the members of **editors-in-chief** for providing their enormous effort to launch this journal. Authors, reviewers and guest editors are always welcomed. Since it is our first Endeavour, I strongly urge all of you to cooperate us through comments and suggestions.

I hope in advance for your valuable contributions to ***Journal of Maize Research and Development.***

Thank you all.

Govind K.C.
NMRP Coordinator
November15, 2015

A Message from Editors-in-Chief

National Maize Research Program under Nepal Agricultural Research Council (NARC), Nepal is launching for the first time in the history of commodity specific open access journal "*Journal of Maize Research and Development*" in Nepal. It will also fill a niche that was hitherto unoccupied by other agricultural journals, and because there is no other journals dedicated exclusively to maize research and development in Nepal. It will help the scientific and farming communities who are directly or indirectly involved in maize research and development across the globe. We will publish one issue annually at the end of December and will contain more than ten articles on maize R&D consisting of breeding, plant protection, crop and soil fertility management and socio-economics. The Editorial Board is composed of professional researchers from NARC and other national and international research and educational institutions. Maize research and development studies carried-out within and outside the country can be retrieved from a single journal. It may help to minimize the duplication of works and misuse of resources in maize R&D.There might be some weaknesses in its quality too. We, therefore, seek constructive feedback to improve it's quality in future. We also expect the higher number of articles in our future issues from authors and institutions. Over the next year, we also plan several new initiatives to make the journal more exciting, popular and useful to our readers. We assure that under the active collaboration of the concerned scientists and institutions, we certainly will improve the quality of our journal in future.

Jiban Shrestha and Tika Bahadur Karki
Editors-In-Chief

Table of Contents

Guidelines to authors:

The Journal of Maize Research and Development will publish original research and review articles related to maize research. The articles from both within and outside the country shall be considered for publication. Authors interested to publish their article/s in the journal are requested to submit with cover letter providing three copies of each manuscript written on one side of A4 size (8.5- × 11.0-in) paper in single space (New Times Roman, Font Size 12) in MS-Word along with electronic copy of the manuscript. The manuscript submitted for publication in this journal is not returned.

Manuscript Format: All contents in article must be written in English. Papers must be an original work and should not be submitted elsewhere for the publication. Before submission, manuscripts should be reviewed critically by two peer reviewers and revised accordingly. Manuscript should be neatly typed, single spaced (along with tables, figures and references) on A4 paper with 1 inch margin at the top, bottom and left side. Manuscripts should generally be organized in the following order of Title and contact information, Abstract , Keywords, Introduction, Materials and Methods (or Methodology), Results and discussion, Conclusion, Acknowledgments and finally References. The maximum length of the paper must be limited to 20 pages, including tables, graphs and references. The manuscript should be submitted to the Editors-in-Chief of the Journal.

Title of the paper: The title of the paper should be clear, descriptive and informative. The first page should contain the full title in sentence case not exceeding 15 words. The authors' identification should include the author's name (do not use abbreviations), title or designation, organization, address, telephone, fax and email Id.

Abstract: The abstract should be clear, descriptive and not longer than 250 words. It should be citation free and should concisely state the major objective, methodology, major findings and conclusion but should not include diagram, footnotes, equations, or any parenthetical references. The font size of abstract is 10 and font is Times New Roman.

Key words: Key words should normally 4-6 keywords

Introduction: The introduction should be should be succinct and with no subheadings. In this section background information, relevant review of literature and objective of the research should be given. Statements must be supported by citations whenever possible. It should give appropriate background and explain the things that are proposed. It should include short introduction to justify the research and relevant reviews and state the objectives clearly (not more than 200 words).

Materials and Methods:

Detail information on relevant materials and methods used including sampling methods, experimental design, treatments, plot size and any other techniques used in research as well as the year and place of conducting the research should be provided. The statistical methods and tools used in study sould be clearly mentioned.

Results and Discussion:

Results should be presented with clarity and precision should be written in the past tense when describing findings in the authors' experiments. Previously published findings should be written in the present tense. Results should be explained, but without referring to the literature. Discussion, speculation and detailed interpretation of data should not be included in the results but should be in the discussion section.

Discussion should interpret the findings in view of the results obtained in this and past studies on the topic. State the conclusions in a few sentences at the end of the paper. The results and discussion sections can include subheadings. When appropriate, the two sections can be combined.

Conclusion: All relevant items achieved in the researched area should be mentioned in the conclusion. The conclusion should be given after the results and discussion section.

Acknowledgements: Acknowledgements, if any, should be given to funding agencies, organization and key person**.**

Reference Citation: The references should be arranged alphabetically and should follow the American Psychological Association (APA) style. References should also indicate the differences in styles for books, journals, newspapers and other published and unpublished materials. The references should be cited within in the body of paper; otherwise, these references must not come under the reference list.

Tables: Tables should be self-explanatory. Tables should be cited consecutively in the text. Every table must have a descriptive title and if numerical measurements are given, the units should be included in the column heading. Tables should be created using the table function.
Tables should be kept to a minimum and be designed to be as simple as possible. Tables should be prepared in Microsoft Word. Tables are to be typed double-spaced throughout, including headings and footnotes. Each table should be on a separate page, numbered consecutively with Arabic numerals and supplied with a title and footnotes. Tables should be self-explanatory without reference to the text. The details of the methods used in the experiments should be described in the footnotes. The same data should not be presented in both a table and a graph or repeated in the text. Each table with a number and proper title heading should be prepared and sorted appropriately. Use simple grid table without complex formatting structures. Use single (*) and double asterisks (**) to indicate statistical significance and have priority in this order to show 5 and 1% levels of significance, respectively. Do not repeat information in the text presented in charts or graph. Use 10 font size and bold table heading.

Figure legends: Should be typed in numerical order on a separate page. Use Arabic numerals to designate figure numbers and upper-case letters for their parts (Figure 1A). Begin each legend with a title and include sufficient description so that the figure is understandable without reference to the text of the manuscript. Graphics should be prepared with applications capable of generating high-resolution JPEG before pasting into the Microsoft Word manuscript file.
Do not repeat data both in table and figures. Either use table, or graph or figure. Each Figure and/or graph with a number and the proper title heading should be drawn or prepared below the graph/figure.

Others: Heading: center and capitalize the main heading of the paper. Sub heading should be on separate line and capitalize the first letter of the first word.

Scientific names: The scientific name must be given in italic and given with authority. The first letter of the word of cultivar must be capitalized

Trade or brand names: capitalize the first letter of trade or brand names

Abbreviations: Always use abbreviations for standard units such as gram (g), kilogram (kg), hectare (ha), metric ton (t), milliliter (mL), liter (L), centimeter (cm), meter (m) and kilometer (km)

Periods: do not put periods after title and key words. Periods are necessary at the end of table and figure heading.

Formulae: All formulae and equations in the paper should be worked out by means of the programme ‘WORD Equation’. The meaning of all symbols should be given immediately after the equation where these symbols are first used. Equations should be numbered by Arabic numerals, serially in brackets, at the right-hand side. Each equation must be mentioned in the text as Eq. (1), Eq. (2), etc.

Page setup: Font: Times New Roman, Size: 12 points Paper: A4 size, Margin: width at 2.54 cm. Spacing: Single. Text Size: Not exceeding 5000 words.

Reprints: The corresponding (first) author will receive one copy of prints free of charge to be shared with coauthors.

Plagiarism policy: JMRD follows the plagiarism policy. Manuscripts submitted to JMRD should be original and must not be plagiarized. Every submitted article is checked for plagiarism through PlagScan software.If plagiarism is proved after publication of the article, that article will be immediately withdrawn and removed from the website and the concerned authors will be considered ineligible for publication of their articles in JMRD in future.

Submission of undertaking: The all concerned authors are bound to submit an undertaking duly signed by them, which shows that this paper was not submitted elsewhere and was also not plagiarized.

Submission of Paper: When submitting the paper,the authors should provide the contact details (names, affiliations and e-mail addresses) of at least three potential reviewers. The reviewers should be experts in the corresponding field of research, and should be able to provide an objective assessment of the paper. The peer reviewers should not be from the same institutions as the authors of the paper. The paper must be submitted electronically to the following address

National Maize Research Program (NMRP)
Rampur, Chitwan, Nepal
Fax :977-56-592548
Phone : 977-56-591001
Cell phone : 977-9845052780
Email : nmrp2012@gmail.com, mail@nmrp.gov.np
Website: http://nmrp.gov.np

Note: If the paper is accepted, the corresponding author should be asked to fill and sign the copyright form and then send to editorial office.
All papers are subject to security and editorial. The Editors-in-Chief or the Editorial Board do not take any responsibility for damage or loss of submitted papers and is not compelled to return unaccepted papers to the authors whatsoever.

Journal of Maize Research and Development (2015) 1(1):1-9

ISSN: 2467-9305 (Online)/ 2467-9291 (Print)
DOI: 10.5281/zenodo.34284

Status and prospects of maize research in Nepal

Govind KC[1*], Tika B. Karki[1], Jiban Shrestha[1] and Buddhi B. Achhami[1]

ARTICLE INFO

Article history:

Received:
10th August, 2015

Revised:
15th September, 2015

Accepted:
10th October, 2015

Keywords:
Maize, research, status, prospects, Nepal

ABSTRACT

Food and nutritional securities are the major threats coupled with declining factor productivity and climate change effects in Nepal. Maize being the principal food crops of the majority of the hill people and source of animal feed for ever growing livestock industries in Terai of Nepal. Despite the many efforts made to increase the maize productivity in the country, the results are not much encouraging. Many of the maize based technologies developed and recommended for the farmers to date are not fully adopted. Therefore, problem is either on technology development or on dissemination or on both. Considering the above facts, some of the innovative and modern approaches of plant breeding and crop management technologies to increase the maize yield need to be developed and disseminated. There is a need for location-specific maize production technologies, especially for lowland winter maize, marginal upland maize production system, and resource poor farmers. Research efforts can be targeted to address both yield potential and on-farm yields by reducing the impacts of abiotic and biotic constraints. Therefore, in order to streamline the future direction of maize research in Nepal, an attempt has been made in this article to highlight the present status and future prospects with few key pathways.

INTRODUCTION

Maize is the second most important crop after rice in terms of area and production in Nepal. It is a way of life for the hill farmers of Nepal. It is a traditional crop grown for food, feed and fodder. Maize demand has been constantly growing by about 5% annually in the last decades (Sapkota and Pokhrel, 2010). Per capita maize consumption in Nepal was 98 g/person/day (Ranum *et al.*, 2014). Therefore, total quantity of maize requirement for food per year is around 2.9 million mt and the production during 2014 was 2.283million mt, hence the deficit was 0.67 million mt. The feed demand is also increasing at the rate of 11% per annum. There is a need of about 6.46 million mt. feed to run smoothly the existing poultry industries in Nepal, and about 0.5 million mt. of feed has been produced annually by the feed industries in Nepal (114, registered in NFEA). Thus, the demand for maize is also shifting from food to feed for livestock and poultry. For foods, new types of maize-based products such as soups, vegetables, edible oils are in demand. Under such circumstances, the import substitution can only be done by increasing the productivity of maize with the available shrunken land. Winter maize under rice-wheat system has been emerging as a new intervention and it can be an option to increase the maize production in Nepal. The area under winter maize in eastern and central Terai is increasing year after year.

Corresponding author Info:
*Coordinator/Senior Scientist (S4),

1 *National Maize Research Program, Rampur, Chitwan, Nepal*
E- mail:nmrp2012@gmail.com

It is due to the increasing demand of maize for poultry feed. Similarly, winter maize yields are higher due to lower risk of pests and diseases and higher production of CHO/day/unit land among the cereals. Furthermore, the farmers are solely dependent on multinational hybrids. If the international suppliers fail to supply the hybrid seeds, farmers will be prone to leave growing maize duing winter.

Maize statistics: area, production and productivity

In 2005, maize was grown in 849892 ha of land and 1716042 mt of maize grain was produced and in 2014 the area and production was increased by 78869 ha and 567180 mt respectively (MOAD, 2014). The increased in maize productivity during the past decade (2005 to 2014) was only 0.439 mt/ha (Table 1). The yield increment at every five years period since 1970 to 2010 varied from negative (-9.71%) in 1975-1979 to 7.76% in 2011-2014 (Fig 1). The present yield level is quite low to fulfill the country’s demand (Table 1).

Therefore, there is a big yield gap of maize in Nepal as affected by various technological and socio-economical factors (Fig 2).

Table 1. Trend of maize area, production and productivity during 2005 to 2014, Nepal

Particular	Year										Changes in %
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Area	849892	850947	8704011	870166	875428	875660	906253	871387	849635	982761	9.25
Production (mt)	1716042	1734417	1819925	1878648	1930669	1855184	2067522	2179414	1999010	2283222	33.05
Yield (mt/ha)	2019	2038	2091	2159	2205	2119	2281	2501.1	2353	2458	21.74

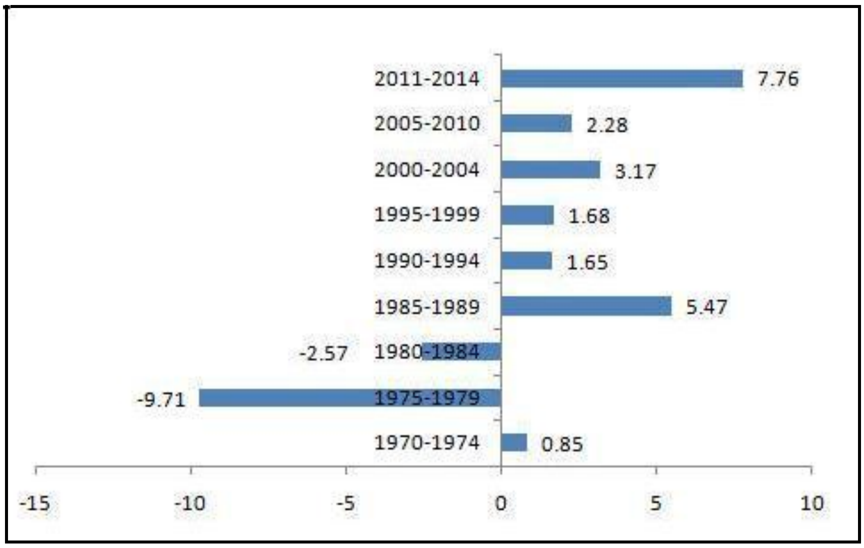


Fig 1. Trends in maize productivity at every 5 years period since 1970 to 2014 in Nepal

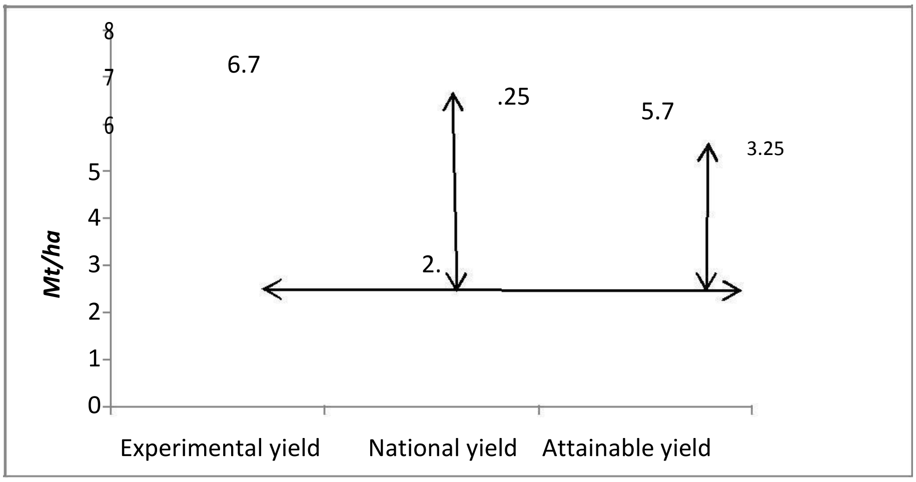


Fig 2. Yield gap of maize in Nepal (NMRP, 2014)

Major constraints

a. Biological

Diseases and Pests in Maize Fields and Stores

Smut (*Sphacelotheca reiliana*) and turcicum blight (*Helminthosporium turcicum*) in the eastern and midwestern/ far-western midhills and highhills; ear rot in the central/western and mid-western/far-western midhills; stalk rot in the mid-western/far-western midhills, terai, and highhills; and downy mildew (*Perona sclerospora spp*.) and leaf firing in the terai were important diseases mentioned by farmers. Banded leaf and sheath blight (*Rhizoctonia solani*) was increasing in severity and prevalence in all environments. Turcicum leaf blight is ubiquitous in hill environments and can cause severe losses if the variety does not have good genetic resistance. Similaarly, gray leaf spot disease is emerging as problematic during rainy season in the hills. White grubs (*Phyllophaga spp*. and *Cyclocephala spp*.), stem borers (*Chilo partellus*), and termites (*Microtermes spp. and Macrotermes spp*.) were major maize field insects in all agro-ecologies. Army worms (*Spodoptera spp*., *Mythimna spp*) and cutworms (*Agrotis spp*. and other species) were also major problems in all agroecologies except the eastern mid hills. Blister beetle was a major problem in the central/western and mid-western/ far-western midhills and the terai, and field cricket a serious pest in the eastern and mid-western/far western mid-hills and high hills. Aphid (*Rhopilosiphum spp*.), locust, red ant, and tassel beetle were also reported by farmers. Weevils (*Sitophilus* spp.) and Angoumois grain moth (*Sitotroga cerealella*) were major problems in stored grain (Paudyal *et al*., 2001) throughout the country.

b. Management

- ***Soil fertility***

Among important recent changes are a reduction in livestock numbers, forest degradation, and reduced availability of labor, development of community forest and stall-feeding of cattle led to reduction in amount of manure (Turton *et al*., 1995). The reasons for low use of chemical fertilizer included high cost, non-availability at key times and a lack of knowledge of their use. There are no updated recommendation onthe doses of fertilizer for high yielding hybrids, winter, spring and summer season, rainfed and irrigated maize.

- ***Plant population at harvest***

One factor that contributes to low system productivity is faulty thinning practices that lead to sub-optimal plant populations at harvest. However, information on optimal plant populations is lacking for maize-millet systems in these regions (Karki *et al*., 2014). Farmers generally plant higher seed rates and keep the higher densities of plant (92000) during vegetative growth stage and later on reduce up to 30,000 plants per hectare at harvest. The recommended plant density of 53,333/ha seems quite low in case of hybrid and spring maize. Therefore, there is a need to recommend the appropriate plant population for different seasons, practices and varieties.

- ***Weed infestation***

Weed cause major yield losses worldwide with an average of 12.8 % despite weed control applications and 29.2% in the case of no weed control (Oerke and Steiner, 1996). The loss caused by weed in maize ranges 40-70% (Mandal, 2000) and yield loss depend on type of weed flora and its severity. At ARS Pakhribas (eastern mid hill of Nepal) experimental result showed weedy environment resulted yield reduction up to 70% in maize (Mishra, 2004). None of the weed management practices are being adopted by farmers except manual weeding in maize.

- ***Seed***

In 2009, seed replacement rate of rice, maize and wheat was: 9 percent, 7 percent, and 9 percent, respectively indicating that over 90 percent of the required seed of major cereals was supplied by the informal sector. For self pollinated crops recommend replacement rate is 25 percent. Likewise, for cross pollinated crops, the replacement rate is 33 percent and for hybrids it is 100 percent (SQCC, 2013). Of the total requirements of the cereal crop seeds, contribution of the formal sector is less than 10% and quality is a constraint to productivity. Large volume of low quality hybrid and other seeds are imported from India and distributed to the farmers through agrovets, especially in the bordering districts causing occasional crop failure in the past (MOAD, 2012). Please see the SRR for different crops in seed vision 2025.

▪

Water management

The total irrigated area in Nepal is only about 1331521 ha (MOAD, 2014). More than two thirds of the maize is produced in the mid hills and high hills during summer season and is mostly grown under rainfed condition. Delay in monsoon during planting, uneven distribution of rainfall and prolonged drought during crop season may affect the crop yield adversely. Water stress due to drought is probably the most significant abiotic factor limiting plant and also crop growth and development (Khalilli *et al*., 2013). The very limited area under winter and spring maize in Terai is irrigated.

c. Socio-economic

Maize is predominantly grown in the hills and the farm sizes are also quite smaller compared to Terai region. Maize farming is therefore considered as subsistence farming in Nepal. It is regarded as a staple food of hill people. Staple commodities such as rice, wheat, potato and vegetables have higher commercialization rates (30-50%) than maize and fruits (15-25%) (ADS, 2014). The productivity is adversely affected by the shortage of agricultural labor (Joshi *et al*., 2012). Due to an inadequate policy intervention for prioritization of agriculture research, NARC, is suffering from inadequate operational budget as a consequence maize research is also being affected.

NMRP and its limitations

NMRP have modest facilities of land for research and seed production, disciplinary and multidisciplinary research projects funded by NARC, some scientific and technical staffs, and laboratories. It also works in collaboration with CIMMYT and ICRISAT, the international CGIAR organizations. In particular, NMRP is incessantly suffering from inadequate research funds, inadequate and no fixed term research staffs, lack of motivational schemes for the research staffs including exposure visits and training, poor technology delivery mechanisms, and inadequate system based researches. Disciplinary laboratories like soil, seed, entomology, plant pathology, plant breeding and agri-mechanization are not in full operation.

Opportunities

There are tremendous opportunities to increase the maize production there by narrowing down the wider yield gap and horizontal expansion in winter season. Although maize yields increased slightly (0.5% per annum), the present level (2.458 mt/ha) has not kept pace with the rapid growth of the population (1.35 per annum). Poultry industries need about 664,000 mt of feed annually in the country where maize is a major source of it. Maize demand is increasing at the rate of 11% per annum in Nepal. To fulfill the growing demand of milk, meat and meat productions, we are importing about 45% of maize to be used for feed from India. While the import of food items is reduced, the only option we have is to increase the production through vertical and horizontal expansion of agricultural commodities. Under such condition, maize can play the role of economic engine of the country due to maize being a high yielding cereal; its area in Terai can be expanded during winter to feed the people and livestock. Development of non-conventional hybrids for short-term and conventional hybrids for long-term is the best alternative to increase production and productivity of maize in Nepal (Gurung *et al*., 2011). Furthermore, the special purpose maize like quality protein maize, sweet corn, baby corn and pop corn can also be grown in accessible areas to substitute the imports.

Emerging issues in maize production

The conventional maize production system needs to be converted into modern, resource use efficient and climate smart under the pretext of stagnant productivity as a result of limited area expansion, low yield potential of the existing genotypes, imported hybrid seed, declining

soil fertility, and emergence of new pest species, labor and water. Therefore, the research should focus on utilizing the latest tools of plant breeding for the development of stress resilient maize genotypes, hybrid seed production effort, climate smart, and resource conserving agro-techniques like conservation agriculture.

Key recommendations

1. Varietal:

Production domain	Recommended varieties
High hills (>1500 m. asl)	Ganesh-1 and Ganesh-2
Mid hills (>1000 m. asl)	Mankamana-1, 2,3,4,5 and 6, Deuti, Sitala, Khumal Hybrid 2
Foot hills (Spring maize)	Rampur composite, Arun-1, Arun-2, Arun-3 and Arun-4, Arun-6
Terai/foot hills	Rampur composite
Terai (Winter maize)	Rampur hybrid-2 and Rampur composite

Promising NMRP hybrids: RML-32/RML-17, RML-4/RMl-17, RML-86/RML-96, RML-95/RML-96.

2. Crop management

- No tillage with retention of previous crop residue i.e. conservation tillage (CT) under rice-maize system found superior in terms of grain yields of respective crops and their system yields, soil nutrient status (soil organic matter, nitrogen, phosphorus and potassium), cost of cultivation and hence net return, and non-lodging plants over the farmer's tillage practice of conventional tillage without the crop residue (FP). Tillage methods and residue levels affected the soil organic matter (SOM %) after the harvest of the crop. NT had the higher SOM of 2.96% compared to conventional tillage methods (2.953). Similarly, residue kept plot had higher (3.194%) SOM over residue removed (2.724). Conservation tillage in maize reduced the impact of drought by lowering soil temperature and surface evaporation, hence increased grain yield.

- In case of conservation tillage in maize, Atrazine herbicide (pre-emergence) application of Atrazine (50%WP) @ 1.5kg ai./ha within 24 hours of planting and in case of no tilled dry direct seeding of rice, Pendimethalin 30% EC @ 6ml/litre of water i.e 550 litres/ha within 48 hours of direct seeding found profitable.

  Planting geometries of 60cm between rows and 25cm between plants for hybrids found suitable in Terai.

- Tank mixture of Atrazine and Glyphosate (Atrazine @ 0.75kg a.i./ha + Glyphosate @2.5 ml/litre of water) or Atrazine (Atrazine @1.5kg a.i./ha as pre emergence) + one hand weeding at 40 days after seeding during spring season maize found better for higher grain yield and net economic return in Terai, Nepal.

- Nitrogen application @ of 180 kg N/ha in three splits (10% at planting, 30% at five leaf stage, 30% at 10 leaf stage and 30% at tasseling resulted the significantly higher grain yield of maize. Cultivation of winter maize practice and Best time of planting for winter maize was last fortnight of September and for spring it was mid February in uplands of Terai.
- For both tilled and no tilled condition, Chinese maize planter that drills the single seed per hill with 100% seed drilling efficiency found suitable for Terai and flat lands.

3. Plant protection

- For Gray leaf spot (GLS) disease the resistant/tolerant varieties are; Manakamana-3, Manakamana-5, Manakamana-6 (for mid-hills) & Ganesh-1 & Ganesh-2 for high hills Rampur Composite (Thai Comp. × Suwan-1) & Sarlahi Seto (Philippines DMR-2)-released in 1975 for Downy mildew resistant.
- For head smut- Tilt (propiconazole) or Bayleton (triademeform) @ 2 g/kg seed has been found effective for the control of disease
- Seed treatment with Apron 35 SD (metalaxyl) @ 3 gm a.i./kg seed was found most effective for the control of downy mildew
- At Chitwan, early planting prior to 14th of May resulted in lighter borer infestation and less subsequent injury from the maize stem borer, than plantings later in the season.
- For maize stem borer management, a commercial mixture of Chloropyriphos 50% and Cypermethrin 5% spray performed better as compare to Confidor 200SL and Furadan 3G whorl placement.
- Maize grains treated with 5% dust of malathion and 2-3 tables of Aluminium phosphide (Celphos) per metric ton found effective to protect against storage pests. In the case of botanicals, Bojho (20 gm/Kg seed) found effective control to maize weevil, where the infestation was only 2.25% during the period of nine months of storage. Furthermore, Neem kernel seed powder @10 g/kg and timur @4g/kg of maize grain and Super grain bag® was found free from storage insect pests up to 6 months.

4. Soil fertility management

- To date general recommendation of fertilizer for maize in Nepal is 120:60:40 $NP_2O_5K_2O$ kg /ha. For spring and summer season maize the recommended doses of Nitrogenous fertilizer can be applied in splits i.e at 30, 45 and 60 days after seeding for the higher grain yield.
- Maize hybrids produced the higher grain yield with 200:60:40 kg NPK/ha during winter in Terai.
- Application of 180: 90: 60 N, P_2O_5 and K_2O plus FYM 10 t/ha for full season maize produced the higher grain yield thereby higher net return.
- Incorporation of Sun hemp as green manure @ 7 t/ha of dry biomass within two months of sowing produced the good yield of winter maize and enhanced the soil nitrogen status.

5. Source seed production

- Around 36000 kg of source seed (breeder, foundation and improved) is produced annually at NMRP and distributed across the country for further seed multiplication.
- Similarly, we produce 29000, 5000 and 1700 kg of foundation seed of rice, wheat and sun hemp and distribute to the various farmer's groups for further seed production.

.

Research priority

To alleviate the constraints of maize production, both varietal development and crop management research need to be implemented in an integrated approach. There is a need for location-specific maize production technologies, especially for lowland winter maize, marginal upland maize production system, and resource poor farmers. Research efforts can be targeted to address both yield potential and on-farm yields by reducing the impacts of abiotic and biotic constraints.

In order to address the aforementioned problems the following actions need to be taken:

1. Germplasm collection, exchange, evaluation and utilization
2. Development of stress (drought, heat, cold , low nutrient and high density) resilient high yielding hybrids and open pollinated varieties of maize for different production ecologies
3. Long term research to develop the improved pest resistant germplasm that is adapted to nutrient deficiencies and other stresses need to be enacted
4. Application of modern tools of breeding like Marker-Assisted and Genomics for the fast track and precision breeding program in collaboration with CIMMYT and other concerned organizations
5. Low cost resource conserving production technologies
6. Source seed production and distribution system throughout the country
7. Development of quality protein maize for nutritional enhancement
8. Bridging the technology generation and delivery system through outreach research program
9. Collaboration with international CGIAR organizations and multinational companies
10. Strengthen the public-private partnership for technology generation and dissemination

Maize research areas

1. Variety development
2. Soil fertility management and agronomy
3. Plant pathology and entomology
4. Seed production technology
5. Technology dissemination
    - Technology verification in farmer's field
    - Periodic technical brochure publication
    - Training for Resource Person of Development Agencies
    - Source seed supply
    - Updating the NMRP websites (For farmers)

Capacity building

- Technical exposure (short term training and visit) to research Scientists is necessary.
- International linkage for seed materials and technical backstopping
- Strengthening scientific research team of NMRP breeding unit
- By 2020, at least two more centers of maize research one in low to mid, and another in high hills should be established.

REFERENCES

ADS. (2014). Agriculture Development Strategy (ADS). Ministry of Agricultural Development Singhdurbar. Kathmandu, Nepal.

Basnyat, B. (2010). Improving seed security through the expansion of seed multiplication farms in the public, private and cooperative sectors in Nepal. Economic Policy Network II, MOF/ADB, Kathmandu December 2010.

Joshi, K.D., Conry, C., & Witcombe, J.R. (2012). Agriculture, seed, and innovation in Nepal: Industry and policy issues for the future. Project Paper. International Food Policy Research Institute. www.ifpri.org.

Karki, T.B., Gadal, N., & Shrestha, J. (2014). Studies on the conservation agriculture based practices under maize based (*Zea mays* L.) based system in the hills of Nepal. *Int.J.Curr.Microbiol.App.Sci* 3(10), 990-1002

Karki, T.B., Sah, S.K., Thapa, R.B., McDonald, A.J.., & Davis, A.S. (2014). Plant density affects the productivity of maize / fingermillet systems in the Mid hills of Nepal. RRJAAS | Volume 3| Issue 4 | October - December, 2014

Khalili, M., Naghavi, Aboughadareh, M.R.,& Rad,, H.N. (2013). Effects of drought stress on yield and yield components in maize cultivars (*Zea mays* L.). *International Journal of Agronomy and Plant Production.* 4,809 -812.

Mandal, R.C. (2000). Weeds, Weedicides and weed control principles and practices. Agro botanical publisher, Bikaner, India.

MOAD. (2014). Statistical information on Nepalese agriculture 2012/2013. Agri-Business Promotion and Statistics Division. Ministry of Agriculture and Development. Singhadurbar, Kathmandu, Nepal.

MOAD. (2014). Value chain development plan for cereal seed . Government of Nepal Ministry of Agriculture Development Project for Agriculture Commercialization and Trade (PACT).

MOAD. (2012). Statistical information on Nepalese Agriculture . (2012/2013). Agri-Business Promotion and Statistics Division. Ministry of Agriculture and Development. Singhadurbar, Kathmandu, Nepal.

Mishra, M. (2004). Studies on weeds management in maize crop in the eastern hills of Nepal. In: Proceeding of the 24th National Summer Crops Research Workshop, 2004. NARC. Pp. 180-181.

Paudyal, K,R., Ransom, J.K., Rajbhandari, N.P., Adhikari, K., Gerpacio, R.V., & Pingali, PL.. (2001). Maize in Nepal: Production Systems, Constraints, and Priorities for Research. Kathmandu: NARC and CIMMYT.

Sapkota, D., & S. Pokhrel. (2010). Community based maize seed production in the hills and mountains of Nepal: A review. *Agronomy Journal of Nepal* , 1, 107

Turton, C.N., Vaidya, A., Tuladhar, J.K,.& Joshi, K.D. (1995). Towards sustainable soil fertility management in the hills of Nepal. Lumle Agricultural Research Center, Nepal/Natural Resources Institute, Chatham Maritime, UK.

Journal of Maize Research and Development (2015) 1(1):10-20
ISSN: 2467-9305 (Online)/ 2467-9291 (Print)
DOI: 10.5281/zenodo.34285

Tillage and planting density affect the performance of maize hybrids in Chitwan, Nepal

Tika Bahadur Karki[1*], Govind KC[1], Jiban Shrestha[1] and Jitendra P. Yadav[1]

ARTICLE INFO

Article history:
Received:
10th September, 2015 Revised:
25th October, 2015 Accepted:
15th November, 2015

Keywords:
Tillage, density, affect, maize, hybrids

ABSTRACT

To find out whether the different tillage methods at different planting densities affect the performance of maize hybrids, an experiment was carried out at National Maize Research Program, Rampur during spring season of 2013 and 2014. The experiment was laid out in strip plot design with three replications having 12 treatments. The vertical factor was tillage with conservation tillage (No Tillage + residue=NT) and conventional tillage (CT) and the horizontal factor were genotypes (Rampur Hybrid-2 and RML-32/RML-17) and in split planting geometries (75cm × 25cm =53333 plants/ha, 70cm × 25cm=57142 plant/ha and 60cm ×25cm= 66666 plants/ha). In both the years, the highest number of cobs (73,177 and 67638/ha) was recorded at planting density of 66666/ha. NT had the highest no of kernel rows/cob (14.01) as against 12.12 in CT in 2014. The highest number of kernels (27.3 and 29.29) per row was recorded in NT during 2013 and 2014 respectively. Similarly, in 2014, the highest number of kernels were found in RML-32/RMl-17 (29.17/row) and planting density of 53333/ha (28.46/row). In 2013, RML-32/RML-17 produced the highest test weight of 363.94g over the Rampur hybrid-2 with 362.17g. Significantly the highest grain yield of 9240.00 kg/ha in 2013 and 7459.80 kg/ha in 2014 at planting geometry of 65cm ×25cm were recorded. No effects was found by tillage methods for grain yields of maize in 2013, but was found in 2014 (7012.18 kg in NT compared to 6037.59 kg/ha in CT). NT and wider spaced crop matured earlier in both the years; however Rampur hybrid-2 matured earlier to RML-32/RML-17 in 2013. In 2014, harvest index of 47.85 % was recorded in planting geometry of 66666/ha, the highest benefit cost ratio of 1.36 was worked out in NT and 1.46 at the density of 66666/ha. The highest value of 2.46% of soil organic matter was recorded in NT as compared to 2.43% in CT.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops grown mainly during the summer season in Nepal. It is the second most important staple crops after rice both in terms of area and production. Its area, production and productivity in Nepal is 928761 ha, 2283222 Mt and 2458 Mt/ha (MOAD, 2014), respectively. It contributes 3.15% to national GDP and 9.5% to agricultural GDP (MOAD, 2013).

Corresponding author Info:
**Senior Scientist (S3), 1 .Nepal Agricultural Research Council, National Maize Research Program, Rampur, Chitwan, Nepal*
E-mail: tbkarki@nmrp.gov.np or tbkarki2003@gmail.com

Despite the many efforts made, the productivity of maize is almost stagnant or slightly decreasing (MOAD, 2013 and MOAD, 2014). The overall demand for maize driven by increased demand for human consumption and livestock feed is expected to grow by 4% to 6 % per year over the next 20 years (Paudyal *et al*., 2001). Thus, Nepal will have to resort to maize imports in the future if productivity is not increased substantially. The poor yields might be due to poor crop management technologies and poor yielding genotypes coupled with declining soil's productivity and higher production costs. Shortage of agricultural labor has further exacerbated the situation (Joshi *et al*., 2012). Therefore, there is a challenge to identify an alternative agricultural system that conserves soil and improve the fertility and also less labor and reduce the cost of production in Nepal. Conservation tillage involves no or minimum tillage with at least 30% of the crop residue must remain on the soil surface at the time of planting (CTIC, 2015), seems to be promising technology in Nepal too. Among the various biotic factors, maize yield is more affected by variations in plant density than other member of the grass family (Vega *et al*., 2001). Maize differs in its responses to plant density (Luque *et al*., 2006). Liu *et al*. (2004) also reported that maize yield differs significantly under varying plant density levels due to difference in genetic potential. Plant populations affect most growth parameters of maize even under optimal growth conditions and therefore it is considered a major factor determining the degree of competition between plants (Sangakkara *et al*., 2004). The grain yield per plant is decreased (Luque *et al*., 2006) in response to decreasing light and other environmental resources available to each plant (Ali *et al*., 2003). Very recently one maize hybrid Rampur Hybrid-2 has been released for general cultivation and another RML-32/RML-17 is under consideration for release in Nepal. Maize hybrids differ in their response to plant density (Xue *et al*., 2002). As maize does not have tillering capacity to adjust to variation in plant stand, optimum plant population for grain production is important. Unfortunately, there is no single robust recommendation for optimum plant densities, since the density varies with environmental factors such as crop establishment methods i.e. tillage, soil fertility, moisture supply, genotype (Gonzalo *et al*., 2006), planting date, planting pattern, plant population and harvest time. The differential response to plant density in maize cultivars has been reported by Xue *et al*. (2002). Nepal has developed some promising hybrids for the Terai and it is necessary to test, verify and promote them under no till condition, since conservation agriculture has been emerging as the inevitable technology to save labor cost, conserve moisture and increase yields thereby sustaining productivity. The aim of this study is to determine the optimum planting density of maize hybrids under various tillage methods in Nepal.

MATERIALS AND METHODS

Experimental site

A field experiment was conducted during spring season (February to June) of 2013 and 2014 in National Maize Research Program (NMRP) farm, Rampur, Chitwan, Nepal. The experimental site is 10 km far in South-West direction from headquarter of Chitwan district, Bharatpur. It is located at 27^0 37'North latitude and 84 ^{0} 25' East longitudes with an elevation of 256 meter above mean sea level. Experimental soil was sandy-loam in texture with 2.47% of organic matter, 0.13% of total nitrogen, 51.0 and 109.5 kg/ha respectively of available phosphorus and potassium. The experimental site falls under the subtropical humid climate belt of Nepal

which is characterized by three different seasons that prevail in the experimental site: cool winter (November to February), hot spring (March to May), and distinct rainy monsoon season (June to October). The maximum and minimum temperature, relative humidity and rainfall were the weather parameters recorded during crop season of spring 2013 and 2014 (Fig 1 and 2).

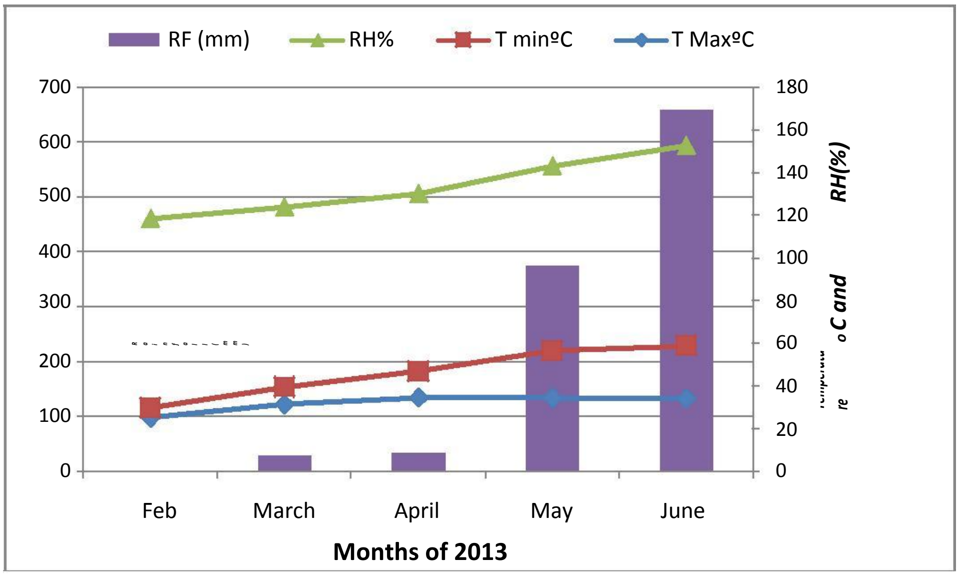


Fig 1. Maximum and minimum temperatures (°c), relative humidity (%) and rainfall (mm), 2013

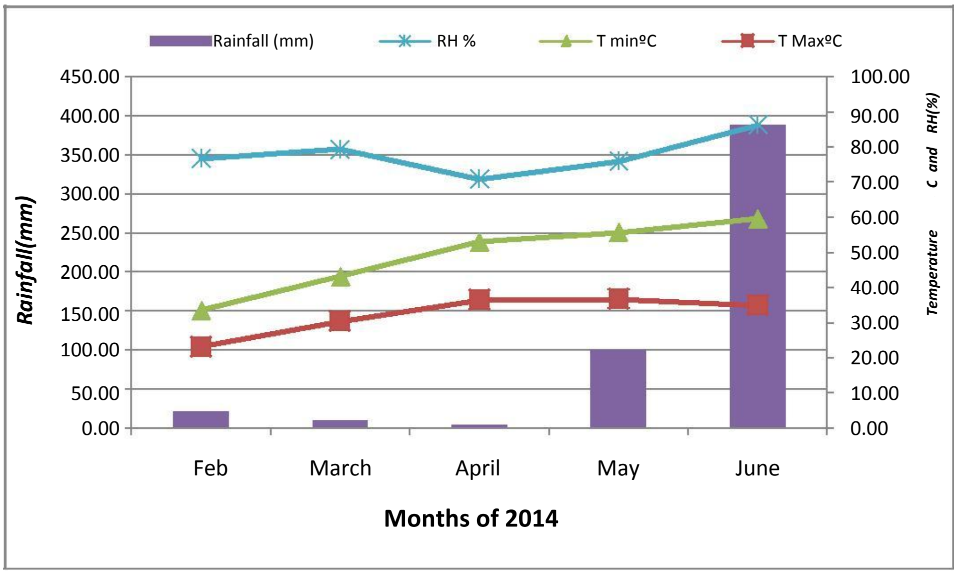


Fig 2. Maximum and minimum temperatures (°c), relative humidity (%) and rainfall (mm), 2014

Experimental setup

The experiment was planted during winter season of 2013 and 2014 and the field was laid out in strip plot design with three replications and 12 treatments. The vertical factor was tillage with conservation tillage (no till + crop residue=NT) and conventional tillage (CT) and the horizontal factor were genotypes (Rampur Hybrid-2 and RML-32/RML-17) and in split planting geometries (75cm × 25cm =53333 plants/ha, 70cm × 25cm=57142 plants/ha and 60cm × 25cm= 66666 plants/ ha). The individual plot size was having 7 rows of 5 meter long as prescribed by the treatments. The three central rows were used as net plot rows for

biometric and agronomical data recording and the remaining 2 rows leaving the two border rows at either side were used for biometrical and phenological observations. Maize crop was planted on 12th and 15th of February and harvested on 27th and 26th of June, 2013 and 2014 respectively. The crop was fertilized with 120:60:40 kg $NP_2O_5K_2O$/ha. Fifty % of the N along with full P and K was applied during seeding and remaining N was splitted into 2 and first half was applied at V7 stage and and the remaining N at pre-tasseling stage of maize. Rest of the crop management operations were done as per the treatment. Weather parameters were recorded from the NMRP's meteorological station. Soil texture, bulk density, organic matter content, pH, total N, available P and K were analyzed using the prescribed laboratory procedures. Cob diameter, no of cobs/ha, no of kernel rows/cob, no of kernels/row, thousand grain weight (g), grain and stover yield (Mg/ha) and economics analysis were measured. Economics of the tested treatments was also worked out. The collected data was processed by MS Excel and analyzed by using ANOVA method of strip-split plot design in GENSTAT Discovery version.

RESULTS AND DISCUSSION

No of plants and cobs per hectare

Tillage methods and genotypes did not affect the no of plants per hectare, however was affected by different plant densities in 2013 and 2014 (Table1 and 3). Planting geometries of 65cm between rows and 25 cm between plants produced the highest number of cobs 67638/ha followed by 57291/ha in spacing of 70×25cm and 53472 in 75×25 cm (Table 1). Similar was the findings of Wang et al. (2015), they also reported that tillage methods did not affect the number of plants and ears per unit area. Similarly, the number of ears per plant was significantly affected by different plant population densities as found by Abuzar et al. (2011).

Plant height of maize

Significant effects of tillage and planting geometries on plant height of maize was observed in 2014. Conventional tillage had the highest plant height of 200.93 cm as against 182.17 cm in NT. The difference between the tested hybrids for plant height was not evident this year. Interestingly, the planting geometries affected the plant height of maize. Higher value of it was recorded in closely spaced plantings than widely spaced planting. Planting spacing of 65×25 cm had the highest plant height of 202.64 cm followed by 189.71cm in 70×25 cm and 182.29 cm and in 75×25 cm (Table 1). Use of high populations heightens interplant competition for light, water and nutrients. When plants are closely spaced, the increased shading effect of the bottom of the plants accelerates the plant growth. A single plant standing by itself dose not grows as fast or grows as tall as plants in a dense population (NDSU, 1999). Sangoi and Salvador (1997) revealed from an experiment with different genotypes and plant densities that height of the plant was significantly influenced by the plant density. Averaged of all cultivars, each increase in 25, 000 plants ha-1 promoted an increase of 2.7 cm in plant height. Mashiqa et al. (2011) found that the plant height was more in higher densities than lower densities, however the plant height was found non-significant due to tillage methods.

Ear height of maize

Unlike the plant height, ear height was not affected by tillage methods revealing the more or less uniform placement of ears. However, the height was higher of 116.86 cm in Rampur hybrid-2 compared to 111.36 cm in RML-32/RML-17. Planting geometries of 65×25 cm had the highest ear height of 116.04 cm followed by 114.6 cm in 70×25 cm and 111.63 cm in 75×25 cm (Table 1).

Cob diameter and length

Significant variation on cob diameter was observed due to tillage, genotypes and planting geometries in 2014. Higher cob diameter of 4.16 was recorded in CT compared to 3.89 cm in NT. Rampur hybrid-2 had the higher diameter of cob compared to RML-32/RML-17. Similarly, the value was more in wider spaced plantings than closely spaced plantings. Similar results were found for cob length due to different hybrids (Table 1). Mashiqa et al. (2011) however found that the cob length and diameter were more in lower plant densities.

Physiological maturity

Crop duration was affected significantly by tillage and planting geometry. Crop from NT matured earlier at 131 days than CT at 136 days. Likewise, wider spaced crop matured earlier than the closed spaced and the crop planted at planting geometry of 75 cm between rows and 25 cm between plants matured earlier at 132 days followed by 133 days in 70×25 cm and 135 days in 65×25 cm spacing (Table 1). Similar was the findings of Araus *et al*. (2008). Correspondingly, in 2014, crop duration was affected significantly by tillage, genotypes and planting geometry. Irrespective of genotypes and planting geometry, crop from NT matured earlier at 130.7 days than CT at 133.8 days. As far as genotypes are concerned, Rampur hybrid-2 took 131.78 days and RML-32/RML-17 matured at 132.78 days. Wider spaced crop matured earlier than the closed spaced and the crop planted at planting geometry of 75cm between rows matured earlier at 130.83 days followed by spacing of 70×25 cm with 132.42 days. The longest duration of 133.58 days was recorded in 60×25cm (Fig 3). Similar results were found by Amanullah *et al*. (2009) and reported that physiological maturity was delayed in those plots maintained at higher plant density. This suggests that dense planting might have slightly slowed down the rate of plant development because of more competition in dense population (Hamid and Nasab, 2001).

Number of kernel rows/cob

Number of kernel rows/cob varied due to tillage methods but not by different planting geometries and genotypes. NT had the higher (14.01) no of kernel rows per cob as against the 12.12 in CT (Table 2). In the past year, number of kernel rows/cob did not vary due to tillage, genotypes and planting geometry. Both the methods of tillage (NT and CT) produced the similar number of kernel rows in a cob. It might be due to the similar availability of soil moisture, nutrients and solar radiation for photosynthesis. However, the rows were more in CT plot and planting geometry of 75cm between rows and 25cm between plants. The two hybrids Rampur Hybrid-2 and RML-32/RML-17 were having the same number of kernel rows in a cob (Table 3).

Number of kernels/row

Differences due to various tillage methods, genotypes and planting geometry were evident for the number of kernels/row. Significantly the highest number of kernels per row was recorded in NT (29.29) over CT (25.911), RML-32/RMl-17 (29.17) against Rampur hybrid-2 (26.02) and in 75×25 cm spacing (28.46) (Table 2). Similarly, the difference due to genotypic and planting geometry was not evident for the number of kernels/ row. Last year, significantly the highest number of kernels per row was recorded at the planting geometry of 60cm between rows and 25cm between plants. Tillage methods affected it and were higher of 27.3 rows in NT as against the 25.8 in CT (Table 3). Similar findings were also reported by Sornpoon and

Jayasuriya (2013), where they did not found any difference in number of kernels per row of maize.

Thousand grain weight

Except planting geometry, differences were observed non significant due to tillage and genotypes on the thousand grain weight of maize. Cropping geometry of 75×25cm produced the highest value of it (285.61g). Thus the higher thousand grain weight was observed in wider spaced than closely spaced planting (Table 2). During the year 2013, except genotypes, no differences were observed due to tillage and planting geometry on the thousand grains weight of maize. But, RML-32/RML-17 produced the highest test weight of 363.94 g over the Rampur hybrid-2 with 362.17g. However, NT had higher test weight to CT. Similarly, slightly a higher test weight was observed in wider spaced planting than closely spaced (Table 3). Shahzad *et al.* (2015) reported that thousand grain weights decreased with increasing planting density. Maximum thousand grain weight of 253 g was recorded from lowest plant density of 65000 plants/ha which is at par with 80000 plants/ha with thousand grain weight of 250 g. Minimum thousand grain weight of 242 g was recorded from the highest planting density of 95000 plants/ha.

Grain yield

Grain yield of maize was significantly affected by tillage and planting geometry. Genotypic differences between the hybrids (Rampur Hybrid-2 and RML-32/RML-17) were not observed. The highest grain yield of 7012.18 kg/ha was harvested from NT as against the 6037.59 kg/ha in CT. Similarly, planting at 65×25 cm spacing produced the highest grain yield of 7459.80 kg/ha over 75 × 25cm with 6080. 91 kg/ha (Table 2). Likewise, the variation in grain yield was evident due to planting geometry and was significantly higher (9.24 Mg/ha) in planting geometry of 60cm between rows and 25cm between plants in the year 2013 (Table 3). It is mainly due to the higher number of cobs per hectare in the aforementioned planting geometry. Board *et al.* (1992) observed greater light interception in the narrow row culture (0.5 m) compared to the wide row culture (1 m). They noted that this occurred during vegetative and early reproductive periods of plant growth. Similarly, Zhang *et al.* (2008) noted that the best distribution of light is attained in systems with narrow strips and high plant densities. Increasing plant density through narrow row planting of maize could increase light interception and consequently increase grain yield. Just like other resources, nitrogen (N) uptake seems to be closely related to plant spacing.

Stover yield

Stover yield of maize was also significantly affected by tillage and cropping geometry. Genotypic differences among both the hybrids Rampur Hybrid-2 and RML-32/RML-17 were not observed. The highest Stover yield of 7863.95 kg/ha was harvested from NT as against 6879.58 kg/ha in CT. Similarly, planting at 65×25 cm spacing produced the highest grain yield of 8125.41 kg/ha over 70 ×25cm with 6888.30kg/ha in 2014 (Table 2).

Harvest Index

Similar to grain yield, harvest index (HI) was also significantly varied due to tillage and planting geometries during the year 2014. The highest Stover value of 47 % was derived in NT as against 46% in CT. Similarly, planting at 65×25 cm spacing produced the highest HI of 47.85 % over 65 x 25cm with 46.07 %. However, the variation was not evident due to tested hybrids for the stated trait (Table 2). Variations in grain yield can be attributed predominantly to variations in kernel number. In a study of four maize hybrids grown at plant

densities ranging from 0.5 to 24 plants/m^2, grain yield ranged from 241 to 22 g/plant ; 87% of the

variation in grain yield per plant at the two plant density extremes was attributable to variation in kernel number, as kernel weight only ranged from 278 to 188 mg kernel 1 (Tollenaar et al., 2000a). Hence, harvest index is mainly a function of the number of kernels (per plant or per m^2) during the grain filling period.

Table 1. Effect of tillage, hybrids and planning densities on the crop performance of spring maize, Rampur, 2014

Treatment	No of plants /ha	No of cobs /ha	Plant height (cm)	Ear height (cm)	Cob diameter (cm)	Cob length (cm)	Physiological maturity (days)
Tillage methods							
CT	58379	59351	200.93	113.64	4.16	15.57	135.78
NT	58425	59583	182.17	114.58	3.89	13.92	131.94
F-test	NS	NS	*	NS	***	*	**
$LSD_{0.05}$	-	-	18.55	-	0.12	0.75	0.500
Hybrids							
Rampur hybrid-2	58518	59675	194.04	116.86	4.10	14.59	133.78
RML-32/RML-17	58287	59259	189.06	111.36	3.95	14.91	133.94
F-test	NS	NS	NS	**	*	NS	NS
$LSD_{0.05}$	-		-	4.28	0.12	-	-
Plant densities							
D1	65972	67638	202.64	116.04	3.96	14.70	135.25
D2	56180	57291	189.71	114.67	4.05	14.16	133.50
D3	53055	53472	182.29	111.63	4.07	15.38	132.83
F-test	***	**	**	**	**	**	**
$LSD_{0.05}$	557.2	733.90	18.55	4.28	0.12	0.48	0.500
CV,%	1.40	1.80	14.10	5.40	4.20	7.40	3.5
Grand mean	58402	59467	191.55	114.11	4.03	14.75	133.86

Note: NT=No Tillage, CT=Conventional Tillage, D1=60×25cm, D2=70×25cm, D3=75×25cm

Economic analysis

Irrespective of tillage and genotypes, the highest net return of NRs, 51032.22/ha was worked out in planting geometry of 60×5cm followed by 20184.74/ha in 75×25cm and NRs.19045.18/ha in 70×25cm. Rampur hybrid-2 recorded the highest value of net return NRs.32452.64/ha over RML-32/RML-17 with NRs. 27722.12 per hectare (Table 3). ANOVA revealed that the higher benefit cost ratio (BC) ratio of 1.36 was worked out in NT as compared to 1.18 in CT. Among the planting geometries, planting at 60 cm between rows and 25 cm between plants produced the highest 1.46 BC ratio as compared to 1.19 in 75×25cm and. 1.16 in 70×25cm spacing in 2014 (Table 2 and 3). Bisht et al. (2012) also reported the similar results and the found in Pantnagar that higher net return from the higher plant densities.

Soil properties

The experiment has been carried-out since 2012 winter season and completed the three seasons. Soil pH was found to be not affected by different tillage methods, genotypes and planting densities. Unlike the soil pH, soil organic matter was found to be affected by tillage methods. The highest value of soil organic matter (2.46%) was recorded in NT as compared to 2.43% in CT (Table 5).

CONCLUSION

To sum up, planting geometry of 65 cm between rows and 25cm between plants having 66666 plants/ ha performed better in terms of grain yields and economics compared to the recommended density of 53333 plants/ha. Of the two hybrids, RML-32/RML-17 was found to be superior in terms of grain yield and related parameters in contrast to Rampur hybrid-2. Planting of maize in no tilled field with the previous crop's residue (maize stover) kept on the soil surface increased the soils' organic matter content over conventional tillage practice. The future plausible studies need to be concentrated on physiological basis of differential planting geometries on crop performance of maize hybrids developed by NMRP.

Table 2. Effect of tillage, hybrids and planting densities on the crop performance of spring maize, Rampur, 2014

Treatment	NKR/Cob	NK/row	TGW (g)	Grain yield (kg/ha)	Stover yield (kg/ha)	HI (%)	BCR
Tillage methods							
CT	12.12	25.91	284.57	6037.59	6879.58	46.60	1.18
NT	14.01	29.29	283.73	7012.18	7863.95	47.07	1.36
F-test	**	**	NS	**	*	*	*
$LSD_{0.05}$	0.51	1.71	-	281.60	576.8	0.29	0.11
Hybrids							
RH-2	14.31	26.02	284.51	6630.12	7471.99	46.88	1.29
RML-32/RML-17	14.00	29.17	283.78	6419.65	7271.53	46.79	1.25
F-test	NS	**	NS	NS	NS	NS	NS
$LSD_{0.05}$	-	1.71	-	-	-	-	-
Plant densities							
D1	14.08	27.79	283.16	7459.80	8125.41	47.85	1.46
D2	14.07	26.54	283.67	6033.96	6888.30	46.58	1.16
D3	14.05	28.46	285.61	6080.91	7101.58	46.07	1.18
F-test	NS	**	**	**	***	**	**
$LSD_{0.05}$	-	1.71	1.33	281.60	576.8	0.29	0.11
CV,%	5.30	9.00	7.2	12.90	11.40	0.90	12.5
Grand mean	14.07	27.60	284.15	6524.89	7371.76	46.83	1.27

Note: NK=no of Kernel, NKR=No of Kernel Rows, TGW= Thousand Grain Weight, BCR=Benefit Cost Ratio, NT=No Tillage, CT=Conventional Tillage, D1=60×25cm, D2=70×25cm, D3=75×25cm

Table 3. Grain yield and related parameters of two hybrids Rampur Hybrid-2 and RML-32/RML-17 under various tillage methods and planting geometries in Rampur, during spring, 2013

Treatments	No of cobs/ ha	NKR/Cob	NK/row	TGW (g)	Grain yield (Mg/ha)
Tillage methods					
CT	62120	14	25.8	362.5	8.35
NT	64962	13.7	27.3	363.61	8.36
F-test	*	NS	*	NS	NS
$LSD_{0.05}$	1831.1	-	1.06	-	-
Hybrids					
Rampur Hybrid-2	64205	13.8	26.4	362.17	8.32
RML-32/RML-17	62876	13.8	26.7	363.94	8.39
F-test	NS	NS	NS	*	NS
$LSD_{0.05}$	-	-	-	1.61	-
Plant densities					
D1	64942	13.8	26.1	362.5	9.24
D2	63603	13.8	26.5	363.08	7.95
D3	62077	14.6	27.1	363.58	7.88
F-test	*	NS	NS	NS	**
$LSD_{0.05}$	2242.7	-	-	-	0.72
CV,%	4.2	3.2	5.8	3.6	8.3
Grand mean	63541	13.9	26.6	363.06	10.36

Note: Note: NK=no of Kernel, NKR=No of Kernel Rows, TGW= Thousand Grain Weight NT=No Tillage, CT=Conventional Tillage, D1=60×25cm, D2=70×25cm, D3=75×25cm

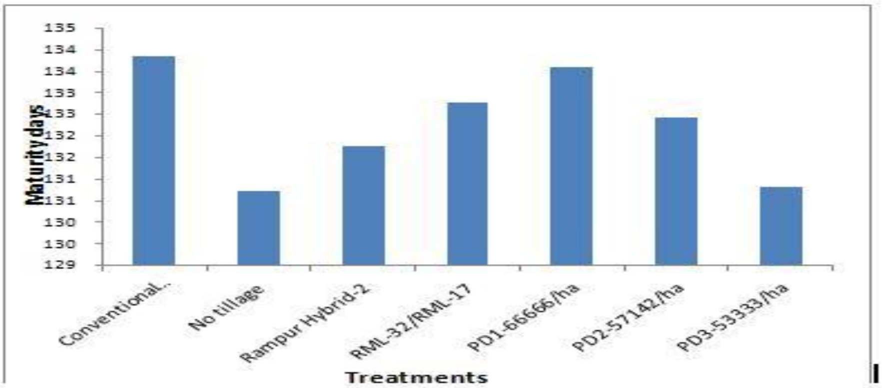


Fig 3. Physiological maturity of Rampur Hybrid-2 and RML-32/RML-17 under various tillage methods and planting geometries in Rampur, during spring, 2013

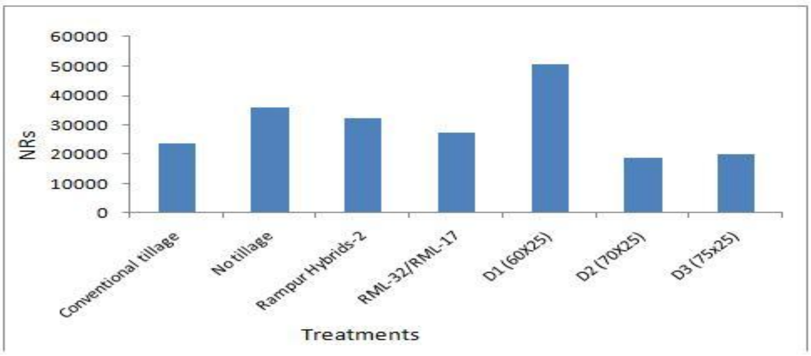


Fig 4. Net return (NRs/ha) as affected b various tillage methods, genotypes and plant densities, Rampur, 2014

Table 4. Summary of the economic analysis of various tillage methods, hybrids and plant densities, Rampur, 2014

Treatment	**Gross return (NRs/ha)**	**Net return (NRs)**	**BC ratio**
Tillage methods			
Conventional tillage	158199.98	23903.98	1.18
No tillage	136266.77	36270.77	1.36
Hybrids			
Rampur Hybrids-2	149598.64	32452.64	1.29
RML-32/RML-17	144868.12	27722.12	1.25
Plant densities			
D1 (60×25)	168178.22	51032.22	1.46
D2 (70×25)	136191.18	19045.18	1.16
D3 (75×25)	137330.74	20184.74	1.19

Table 5. Effect of tillage, hybrids and planting densities on the soil pH and organic matter content, Rampur, 2014

Treatment	**Soil pH**	**Soil organic matter (%)**
Tillage methods		
Conventional tillage	5.46	2.43
No tillage	5.55	2.60
F test	NS	*
$LSD_{0.05}$	0.58	0.03
Hybrids		
Rampur Hybrid-2	5.52	2.50
RML-32/RML-17	5.49	2.51
F test	NS	NS
$LSD_{0.05}$	-	-
Plant densities		
D1 (60×25)	5.46	2.46
D2 (70×25)	5.49	2.51
D3 (75×25)	5.55	2.52
F test	NS	NS
$LSD_{0.05}$	-	-
CV,%	1.5	3.7
Grand mean	**5.50**	2.49

REFERENCES

Abuzar, M.R., Sadozai, G. U, Baloch, M. S., Baloch, A. A., Shah, I. H. Javaid, T & Hussain, N. (2011). Effect of plant population on densities on yield of maize. *The Journal of Animal & Plant Sciences*, 21(4), 692-695.

Ali, R., Khalil, S. K., Raza, S. M. & Khan, H. (2003). Effect of herbicides and row spacing on maize. *Pak. J. Weed Sci. Res.* 9(3-4), 171-178.

Amanullah, R., Khattak, A, & Khalil, S. K. (2009). Plant Density and Nitrogen Effects on Maize Phenology and Grain Yield. *Journal of Plant Nutrition*, 32, 246–260.

Araus, L., Slafer, G.A, Royo, C. & Serret, M.D. (2008). Breeding for yield potential and stress adaptation in cereals. *Crit. Rev. Plant Sci*. 27, 377–412.

Bisht, A.S., Bhatnagar, A., Pal, M.S. & Singh, V. (2012). Growth Dynamics, Productivity and Economics of Quality Protein Maize (Zea mays L.) Under Varying Plant Density and Nutrient Management Practices. *Madras Agric. J.*, 99 (1-3), 73-76.

Board, J. E., Kamal, M., and Harville, B. G. (1992). Temporal importance of greater light interception to increased yield in narrow-row soybean. *Agronomy Journal*, 84, 575–579.

CTIC. (2015). Conservation Technology Information Centre. 3495 Kent Avenue, West Lafayette, Indiana : http://www.ctic.purdue.edu/

Gonzalo, M., Vyn, T.J., Hollan, J.B & McLntyre, L. M. (2006). Mapping density response in maize: A direct approach for testing genotype and treatment interactions. *Genetics*, 173, 331-348.

Hamid, A & Nasab, A. D. M. (2001). The effect of various plant densities and N levels on phenology of two medium maturity corn hybrids. *Iranian. J. Agri. Sci.* 32, 857–874.

Liu, W., Tollenaar, M. & Smith, G. (2004). Within row plant spacing variability does not affect corn yield. *Agron. J.* 96, 275-280.

Luque, S. F., Cirilo, A. G. & Otegui, M. E. (2006). Genetic gains in grain yield and related physiological attributes in Argentine maize hybrids. *Field Crop Res*. 95, 383-397.

Mashiqa, P., Lekgari, L. & Ngwako, S. (2011). Effect of plant density on yield and yield components of maize in Botswana. *World of Sciences Journal*. 1 (7), 173-179.

MOAD. (2014). Statistical information on Nepalese Agriculture 2012/2013. Agri-Business Promotion and Statistics Division. Ministry of Agriculture and Development. Singhadurbar, Kathmandu Nepal.

NDSU. (1999). Equity, Diversity and Global Outreach, North Dakota State University. 205 Old Main, (701) 231-7708.

Paudyal, K.R. & Ransom, J.K. (2001). Resources Use Efficiency and Effective Incentives to Nepalese Maize Farmers. Sustainable Maize Production Systems for Nepal. Proceedings of Maize Symposium. 3-4 December, 2001, Kathmandu, Nepal.

Sangakkara, U. R., Bandaranayake, P. S., Gajanayake, J. N. & Stamp, P. (2004). Plant populations and yield of rain-fed maize grown in wet and dry seasons of the tropics. *Maydica*, 49, 83-88.

Sangoi, L. & Salvador, RJ. (1997). Influence of plant height and leaf number on maize production at high plant densities. Univ. do Estado de Santa Catarina (UDESC), Caixa Postal 281, CEP 88520-000 Lages, SC. Bolsista.

Shahzad, I., Arif, M, Khan, A., Ali Khan, M., Shah, W., & Latif, A. (2015). Effect of Nitrogen Levels and Plant Population on Yield and Yield Components of Maize. *Advances in Crop Science and Technology*. 3, 170.

Sornpoon, W. & Jayasuriya, H.P.W. (2013). Effect of different tillage and residue management practices on growth and yield of corn cultivation in Thailand. *J. Agric Eng Int.*, 15 (3), 86-94.

Tollenaar, M., Dwer, L.M., & Steart, D.W. (2000a). Physiological parameters associated with differences in kernel set among maize hybrids. pp. 115-130. In: M.A. Westgate, K.J. Boote (Eds.), Physiology and modeling kernel set in maize. CSSA Spec. Publ. 51, CSSA/ASA/SSSA, Madison, WI.

Vega, C.R.C., Andrade, F.H, Sadras, V.O., Uhart, S.A. & Valentinuz, O. R. (2001). Seed number as a function of growth. A comparative study in soy-bean, sunflower, and maize. *Crop Sci.* 41, 748–754.

Wang, X., Baoyuan, Z. Xuefang, S. Yang, Y. Wei, M., & Ming, M.A. (2015). Soil Tillage Management Affects Maize Grain Yield by Regulating Spatial Distribution Coordination of Roots, Soil Moisture and Nitrogen Status. PLoS One, 10, 6.

Xue, J., Liang, Z.G.M., Lu, H. ,& Ren, J. (2002). Population physiological indices on density-tolerance of maize in different plant type. *Ying Yong Sheng Tai Xue Bao*, 13, 55-59.

Zhang, L., Vander Werf, W., Bastiaans, L., Zhang, S., Li, B., & Spiertz, J.H.J. (2008). Light interception and utilization in relay intercrops of wheat and cotton. *Field Crops Research*, 107 (1), 29–42.

Journal of Maize Research and Development (2015) 1(1):21-27

ISSN: 2467-9305 (Online)/ 2467-9291 (Print)

DOI: 10.5281/zenodo.34282

Performance evaluation of quality protein maize genotypes across various maize production agro ecologies of Nepal

Jiban Shrestha[1]*, Keshab B. Koirala[1], Ram B. Katuwal[2], Narayan B. Dhami[3], Bhanu B. Pokhrel[4], Bikash Ghimire[5], Hari K. Prasai[6], Arjun Paudel[7], Keshav Pokhrel[8] and Govind KC[9]

ARTICLE INFO

Article history:

Received: 24th August, 2015 Revised: 20th September, 2015 Accepted: 27th October, 2015

Keywords:

Evaluation, quality protein maize and grain yield

ABSTRACT

To identify superior quality protein maize genotypes for grain yield under different agro climatic conditions of terai and hill districts in Nepal, the coordinated varietal trials (CVT) were conducted at Dailekh, Doti, Salyan, Lumle and Pakhribas in 2013 and Salyan, Pakhribas and Kabre in 2014 during summer season and coordinated farmer's field trials (CFFT) at Surkhet and Dailekh in 2013 and Salyan, Pakhribas and Khumaltar in 2014 during summer season. The experiment was carried out using randomized complete block design with three replications for CVT and CFFT. Across the locations and years the superior genotypes found under CVT were S01SIYQ, S01SIWQ-2 and Poshilo Makai-1 where as S99TLYQ-HG-AB, S99TLYQ-B and Poshilo Makai-1 were found superior genotypes under CFFT. The superior genotypes derived from CFFT will be promoted further for similar environments across the country.

INTRODUCTION

Maize is one of the most important staple food crops in Nepal where its area and productivity is 8.49 million hectare and 2.3 t/ha, respectively (MoAD, 2013). It contributes to about 25.02% in total for cereal production, 6.54% in AGDP and 3.15% in GDP (MoAD, 2013). It is also an important feed ingredient for poultry and livestock and hence the demand of quality protein maize (QPM) is increasing. In our country all varieties of maize released so far are normal type except Poshilo Makai-1. Cereal protein contains on average about 2% lysine which is less than one-half of the concentration recommended for human nutrition by Food and Agriculture Organization (FAO) of the United Nations (Prasanna *et al.*, 2001). Normal maize has poor nutritional value for monogastric animals such as humans and pigs because of reduced content of essential amino acids such as lysine and tryptophan. For humans, lysine is the most limiting amino acid followed by tryptophan in maize protein (Kies *et al.*, 1965). The biological value of QPM protein is about 80% that of milk which is about 90% and that of normal maize is only about 45% (FAO, 1992). QPM also provides better quality feed and fodder to poultry, cattle, swine, and fishmeal industries. The majority of hill farm families in Nepal are suffering from protein malnutrition as their major staple food is maize and cannot afford animal protein.

Corresponding author Info:

[1]National Maize Research Program, Rampur, Chitwan, Nepal
[2]ARS Pakhribas, [3]ABD Khumaltar, [4]HCRP Kabre, [5]ARS Dailekh, [6]RARS Doti, [7]RARS Lumle, [8]ARS Surkhet and [9]GRP Salyan

The maize growing environments of Nepal is very diverse and varied along north to south parts of the country. It is the only crop which is adaptive to across different agro-ecological zones because of its great diversity (Ferdu *et al.*, 2002). The improved varieties give high and stable yields across environments where they are adapted (CIMMYT, 1991). The ability to develop high yielding stable cultivars is a primary focus in most breeding programs. The research on the development of quality protein maize varieties is not sufficient in Nepal. Therefore, these trials were conducted to identify superior quality protein maize genotypes in terms of grain production for hills of Nepal.

MATERIALS AND METHOD

Genotypes used

In CVT of 2013 and 2014, the genotypes used in trials were S00TLWQ-B S01SIWQ-2 CLEYAS99-SIWQ S00TLYQ-B S99TLWQ-B S03TLYQ-AB-01 S01SIYQ S03TLYQ-AB-2 Poshilo Makai-1 Farmer's Variety (Rampur Composite). In CFFT of 2013, the genotypes used in trials were S03TLYQ-AB-02, S03TLYQ-AB-01, S99TLYQ-B, S99TLYQ-HG-AB, Poshilo Makai 1 and Farmer's Variety (Rampur Composite). In CFFT of 2014, the genotypes used in trials were Obatampa, RampurSO3FQ-O2, S99TLYQ-HG-AB, S99TLYQ-B, Poshilo Makai-1 and Farmer's Variety (Rampur Composite)

Experimental design and cultural practices

The coordinated varietal trials (CVT) were conducted at Dailekh, Doti, Salyan, Lumle and Pakhribas in 2013 and Salyan, Pakhribas and Kabre in 2014 during summer season and coordinated farmer's field trials (CFFT) at Surkhet and Dailekh in 2013 and Salyan, Pakhribas and Khumaltar in 2014 during summer season. All trials were laid out in randomized complete block design with three replications in CVT and farmer's as replicate in CFFT with three replications and general agronomic practices were done in all trials. The individual plots was 4 rows of 3 m length i.e. 9 m^2 (3 m × 3 m) for CVT and 6 rows of 3 m length i. e. 13.5 m^2 (4.5 m × 3 m) for CFFT where genotypes were seeded at the standard seeding rate of 20 kg/ha. The net area harvested was 9m^2 for CVT and 13.5 m^2 for CFFT. The spaces between row to row and plant to plant were 75 and 25 cm. respectively. In all experiments, two seeds per hill were planted and thinned to single plant per hill after first weeding. Fertilizer was applied @ 120:60:40 kg/ha N:P_2O_5:K_2O, respectively for all the experiments. Half of N and full dose of P_2O_5 and K_2O were applied as basal dose. The remaining half of the N was applied in two splits at knee-high and pre-tasseling/silking stages. Other agronomic practices were carried out as per recommended.

Field Measurements

Plant height, ear height, tasseling and silking day were recoreded. Grain yield (kg/ha) at 15% moisture content was calculated using fresh ear weight with the help of the below formula:

$$\text{Grain yield}\left(\frac{kg}{ha}\right) = \frac{F.W.\left(\frac{kg}{plot}\right)(100-\text{moisture},\%) \times S \times 10{,}000}{85 \times \text{Harvested area}(m^2)}$$

Where,

F.W. = Fresh weight of ear in kg per plot at
harvest Moisture (%) = Grain moisture content at
harvest 85= Required moisture percentage 15%
S= Shelling co-efficient (0.80)

Harvested area= net harvested plot size, m^2

Statistical Analysis

The statistical analysis of the data was done using computer software MSTATC version 1.2 (Freed, 1990) applying 5% level of significance.

RESULTS AND DISCUSSION

The findings of CVT in 2013 summer season showed that at Dailekh, Doti, Salyan, Lumle and Pakhribas the combined analysis across location revealed that all the tested genotypes were highly significant for grain yield, significant for ear height and non significant for plant height. The highest grain yield was obtained by Farmer's Variety (5135 kg/ha) followed by S01SIYQ (5086 kg/ha), Poshilo Makai-1 (4997 kg/ha) and S01SIWQ-2 (4893 kg/ha). The S00TLWQ-B had highest plant height (178.5 cm) while Poshilo Makai-1 had lowest plant height (177.9 cm). Maximum value of ear height was shown by Poshilo Makai-1 (97.9 cm), while minimum value was recorded in S00TLYQ-B (84.1 cm). The genotype × location interaction was non significant for plant height, significant for ear height and highly significant for grain yield. The highly significant G × E interaction indicated that genotypes under different environments behaved differently for the expression of characters of interest. It means a particular variety may not exhibit the same phenotypic performance under different environments or different varieties may respond differently to a specific environment.

The findings of CFFT in 2013 summer season showed that at Surkhet and Dailekh the combined analysis across location revealed that all the tested genotypes were highly significant for tasseling day, silking day, ear height and non significant for grain yield. The highest grain yield was produced by Poshilo Makai-1 (3266 kg/ha) followed by S99TLYQ-HG-AB (3094 kg/ha) and Farmer's variety (3066 kg/ha) and S99TLYQ-B (3036 kg/ha). Farmer's variety had highest ear height (125 cm) while S03TLYQ-AB-02had lowest plant height (95.7 cm). Maximum value of plant height was shown by Farmer's Variety (237 cm), while minimum value was recorded in S03TLYQ-AB-02 (193.5 cm). There was variation in tasseling day; the highest in Poshilo Makai-1 (55.33 day) and lowest in Farmer's variety (52 day). Similarly highest value of silking was given by S99TLYQ-B (58.11 day) and lowest value in Farmer's variety (54.44 day). There was highly significant G × E interaction for tasseling and silking, significant for plant height and non significant for ear height and grain yield.

The highly significant G × E interactions indicated that genotypes performance was inconsistent across testing locations and need to be tested in several locations in order to select stable genotypes.

Table 1. Combined analysis of genotypes for agronomic traits under CVT at Dailekh, Doti, Salyan, Lumle and Pakhribas in 2013 summer season

SN	Genotype	Plant height (cm)	Ear height (cm)	Grain yield (kg/ha)
1	S00TLWQ-B	178.5	91	3958
2	S01SIWQ-2	173.2	86.1	4893
3	CLEYAS99-SIWQ	175.8	87	4725
4	S00TLYQ-B	160.8	84.1	3694
5	S99TLWQ-B	164.7	97.2	4391
6	S03TLYQ-AB-01	179.9	93	4546
7	S01SIYQ	172.6	88.6	5086
8	S03TLYQ-AB-2	174.1	86.1	4835
9	Posilo Makai-1	177.9	97.9	4997
10	Farmer's Variety (Rampur Composite)	179	87.9	5135
F-test,	Genotype	0.652	0.026	<.001
	Location	<.001	<.001	<.001
	Genotype × Location	0.129	0.01	<.001
$LSD_{0.05}$		36.52	38.11	2001.5
CV%		10.5	21.6	21.5

Table 2. Combined analysis of genotypes for agronomic traits under CFFT at Surkhet and Dailekh in 2013 summer season

SN	Genotype	Tasseling day	Silking day	Plant height (cm)	Ear height (cm)	Grain yield (kg/ha)
1	S03TLYQ-AB-02	52.78	56.11	193.5	95.7	2999
2	S03TLYQ-AB-01	54.44	56.89	211.4	107.5	2955
3	S99TLYQ-B	54.44	58.11	228.5	122.1	3036
4	S99TLYQ-HG-AB	55.11	57.44	222.6	114.7	3094
5	Poshilo Makai 1	55.33	57.78	226.5	114.5	3266
6	Farmer's Variety (Rampur Composite)	52	54.44	237	125	3066
F-test	Genotype	<.001	<.001	<.001	<.001	0.770
	Location	<.001	<.001	<.001	<.001	<.001
	Genotype × Location	<.001	<.001	0.039	0.214	0.934
$LSD_{0.05}$	Genotype	1.288	1.238	13.04	9.889	435
	Location	0.7886	0.7581	7.984	6.056	266.4
CV%		2.5	2.28	6.21	9.15	14.85

The results of CVT in 2014 summer season showed that at Salyan, Pakhribas and Kabre the combined analysis across location revealed that all the tested genotypes were highly significant for grain yield, tasseling day, silking day, ear height and significant for plant height. The highest grain yield was obtained by Farmer's variety (4185 kg/ha) followed by S01SIYQ (3645 kg/ha), S01SIWQ-2 (3302 kg/ha) and Poshilo Makai-1 (3275 kg/ha).

Farmer's variety had highest plant height (258.2 cm) while CELEYA S99-SIWQ had lowest plant height (203.8 cm). Maximum value of ear height was shown by Farmer's Variety

(150.9 cm), while minimum value was recorded in CELEYA S99-SIWQ (108 cm). There was variation in tasseling day; the highest in S00TLWQ-B (66.17 day) and lowest in Farmer's variety (61.33 day). Similarly highest value of silking was given by CELEYA S99-

SIWQ (69.17 day) and lowest value in Farmer's variety (64.5 day). There was highly significant G × E interaction for tasseling, silking, ear height, grain yield and significant for plant height. The highly significant G × E interactions indicated that genotypes performance was inconsistent across testing locations and need to be tested in several locations in order to select stable genotypes.

Table 3. Combined analysis of genotypes for agronomic traits under CVT at Salyan, Pakhribas and Kabre in 2014 summer season

SN	Genotype	Tasseling day	Silking day	Plant height (cm)	Ear height (cm)	Grain yield (kg/ha)
1	S00TLWQ-B	66.17	69	237	128.8	1068
2	S01SIWQ-2	64.5	68	223.1	113.8	3302
3	CELEYA S99-SIWQ	66.5	69.17	203.8	108	1098
4	S00TLYQ-B	63.67	66.5	210.1	114.2	3195
5	S99TLWQ-B	63.67	66.83	218.5	119.9	2757
6	S03TLYQ-AB-01	65.17	69	223.2	113.2	2945
7	S01SIYQ	66.5	69.33	236.2	127.8	3645
8	S03TLYQ-AB-02	65.33	68.17	211.1	113.8	2669
9	Poshilo Makai-1	65.67	68.67	221.2	111.5	3275
10	Farmer's Variety (Rampur Composite)	61.33	64.5	258.2	150.9	4185
	Genotype	0.002	0.002	0.018	<.001	<.001
F-test,	Location	<.001	<.001	<.001	<.001	<.001
	Genotype × Location	<.001	<.001	0.55	0.003	<.001
$LSD_{0.05}$		3.247	3.887	3.887	1952	113.3
CV%		2.4	2.8	2.8	7.9	19.3

The findings of CFFT in 2014 summer season showed that at Salyan, Pakhribas and Khumaltar the combined analysis across location revealed that all the tested genotypes were significant for grain yield, plant height and ear height. The highest grain yield was obtained by Farmer's Variety (6651 kg/ha) followed by Poshilo Makai-1 (5970 kg/ha), S99TLYQ-HG-AB (5753 kg/ha) and S99TLYQ-B (5166 kg/ha). Farmer's variety had highest plant height

(258.2 cm) while S99TLYQ-HG-AB had lowest plant height (223.6 cm). Maximum value of ear height was shown by Farmer's Variety (143.8 cm), while minimum value was recorded in S99TLYQ-

B (113.9). The genotype × location interaction was non significant for grain yield, plant height and ear height.

Table 4. Combined analysis of genotypes for agronomic traits under CFFT at Salyan, Pakhribas and Khumaltar in 2014 summer season

SN	Genotype	Plant height (cm)	Ear height (cm)	Grain yield (kg/ha)
1	Obatampa	235.4	121.7	3925
2	RampurSO3FQ-O2	224.6	114.3	5141
3	S99TLYQ-HG-AB	223.6	116.8	5753
4	S99TLYQ-B	226.8	113.9	5166
5	Poshilo Makai-1	225	116.4	5970
6	Farmer's Variety (Rampur Composite)	258.2	143.8	6651
F-test	Genotype	0.003	0.004	0.044
	Location	0.007	0.015	0.003
	Genotype × Location	0.447	0.454	0.668
$LSD_{0.05}$	Genotype	18.33	15.67	1659
	Location	12.96	11.08	1173
CV%		8.23	13.49	31.82

CONCLUSION

- Selection of high yielding QPM genotypes for a particular location is the most important task in QPM development program.
- In CVT, S01SIYQ, S01SIWQ-2 and Poshilo Makai-1 were found high yielding genotypes across years and locations.
- In CFFT, S99TLYQ-HG-AB, S99TLYQ-B and Poshilo Makai-1 were found superior for grain yield genotypes across years and locations.
- Superior varieties in CVT should be further tested in CFFT and superior varieties in CFFT should be forwarded for release and be recommended to farmers of hill districts of Nepal for general cultivation

ACKNOWLEDGEMENTS

The authors were grateful to NARC for financial and NMRP for technical support. They sincerely appreciate cooperation from ARS Dailekh, RARS Doti, ARS Pakhribas, ADB Khumaltar, GRP Salyan, ARS Surkhet, HCRP Kabre and RARS Lumle staffs and team members for their hard work in the implementation of project activities. All the participating farmers are gratefully acknowledged for co-operating in the field trials.

REFERENCES

CIMMYT (1991) High Yielding Varieties Do Not Necessary Yield Less Under Unfavorable Conditions. CIMMYT Annual Report 1990. Mexico DF.

FAO (1992) Maize in human nutrition. Journal of Nutrition.FAO, Rome. 1980, 110: 1070-1074.

Freed, R.D. (1990). MSTATC version 1.2. Michigan State. Uni., Michigan, USA.

Ferdu, A., Demissew, K., & Birhane, A. (2002) Major Insect Pests of Maize and their Management: A Review in: Nigussie M., D. Tanner and A.S. Twumasi (Eds.) Enhancing the Contribution of Maize to Food Security in Ethiopia. Proc. 2nd Nat. Maize Workshop, Addis Ababa Ethiopia, 12- 16 Nov. 2001.

Kies, C., Williams, E.R., & Fox, H.M. (1965) Determination of first-limiting nitrogenous factors in corn protein for nitrogen retention in human adults. *Journal of Nutrition.* 86, 350.

MoAD (2013) Statistical Information on Nepalese Agriculture 2012/13. Government of Nepal, Ministry of Agriculture and Cooperatives. AgriBusiness Promotion and Statistics Division. Singha Durbar, Kathmandu, Nepal.10p

NMRP (2011). Annual Report 2010/11. National Maize Research Program (NMRP), Rampur, Chitwan, Nepal

Prasanna, B.M., Vasal, S. K., Kassahun, B., & Singh, N.M.. (2001) Quality protein maize. *Current Science* , 81 (25).

Journal of Maize Research and Development (2015) 1(1):28-52

ISSN: 2467-9305 (Online)/ 2467-9291 (Print)
DOI: 10.5281/zenodo.34292

A review on important maize diseases and their management in Nepal

Subash Subedi*

ARTICLE INFO

Article history:
Received:
5th September, 2015
Revised :
25th October,2015
Accepted:
10th November, 2015

Keywords:

Maize, disease, control/ management

ABSTRACT

In Nepal, maize ranks second after rice both in area and production. In recent years, maize area and production has shown a steady increase, but productivity has been low (2.46 t/ha). The major maize producing regions in Nepal are mid hill (72.85%), terai (17.36%) and high hill (9.79%) respectively. A literature review was carried out to explore major maize diseases and their management in Nepal. The omnipresent incidence of diseases at the pre harvest stage has been an important bottleneck in increasing production. Till now, a total of 78 (75 fungal and 3 bacterial) species are pathogenic to maize crop in Nepal. The major and economically important maize diseases reported are Gray leaf spot, Northern leaf blight, Southern leaf Blight, Banded leaf and sheath blight, Ear rot, Stalk rot, Head smut, Common rust, Downy mildew and Brown spot. Information on bacterial and virus diseases, nematodes and yield loss assessment is also given. Description of the major maize diseases, their causal organisms, distribution, time and intensity of disease incidence, symptoms, survival, spreads, environmental factors for disease development, yield losses and various disease management strategies corresponded to important maize diseases of Nepal are gathered and compiled thoroughly from the available publications. Concerted efforts of NARC commodity programs, divisions, ARS and RARS involving research on maize pathology and their important outcomes are mentioned. The use of disease management methods focused on host resistance has also been highlighted.

INTRODUCTION

Plant diseases are of paramount importance to humans because they damage plants and plant products on which humans depends for food, clothing, furniture, the environment and in many cases the housing. The kinds and amounts of losses caused by plant diseases vary with the plant or plant products, the pathogen, the locality, the environment, the control measures practiced and combination of these factors (Agrios, 2005). Disease is one of the major biotic constraints to reduce crop yield and also deteriorate the quality of product that ultimately reduce the market price. The reason behind the low productivity of most of the crops in Nepal is due to the attack of many

Corresponding author Info:
**Scientist/Plant Pathologist*
National Maize Research Program, Rampur, Chitwan Nepal Agricultural Research Council (NARC) Phone: 977-9845066695
E-mail: subedi.subash1@gmail.com

plant diseases at different stages of crop. Maize is a most important cereal crop in Nepal and also the principal staple cereal diet of most of the Nepalese people who mainly lives in hilly region. Maize contributed 24.93% in total edible cereal grain production in Nepal. The total area under maize production is 928,761 ha in Nepal where mid hill, terai and high hill occupies 72.85, 17.36 and 9.79% respectively (MOAD, 2014). The national average yield of maize is 2.46 mt/ha which is quite low compared to neighboring countries. The Nepalese maize yield level at present is far below than potential yield. There is a wide gap between potential yield of maize varieties having 6.7 t/ha (on-station experimental yield), attainable yield of about 5.7 t/ha (on farm yield with improved practices) and national yield of 2.4 t/ha (Figure 1) (NMRP, 2014). There are various biotic and abiotic yield limiting factors in maize of which diseases and poor crop management are important ones. Maize plants are affected by wide range of pathogens with fungal and bacterial diseases being the most important in Nepal.

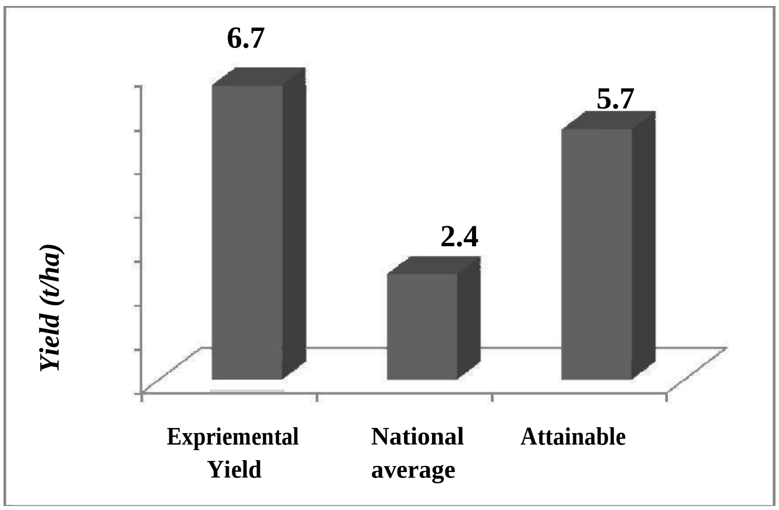


Figure 1. Yield gap of maize in Nepal

Maize is susceptible to many fungal pathogens, to a lesser no of pathogenic bacteria, nematodes and viruses, to least one mycoplasma like organisms and one parasitic like higher plant. Seventy-five fungal and three bacterial species have been recorded pathogenic to maize crop in Nepal (Manandhar, 1997). Several of them are economically important. Besides several nematode species were isolated that are known to be pathogenic in maize (Manandhar, 1997). Some virus diseases have been suspected but have not been verified in Nepal (Manandhar, 1983). Important maize diseases and their status in different agro-ecological regions are presented in Table 1. Maize disease investigation was initiated in 1964-65 when there was not one improved variety of maize in the country (Manadhar, 1983). The preliminary investigation of maize diseases was initiated along with a general plant disease survey by the Plant Pathology Division, Khumaltar (Khadka and Sah, 1967). Among the diseases recorded, only a few are economically important. The major diseases have been primarily managed by the development of the resistant varieties. This paper focused on major maize diseases which are considered serious constraints to productivity and production of maize in Nepal.

Table 1. List of maize diseases and their first record of prevalence (Year/Location) and status in Nepal

	Disease	Pathogen	First Record of disease prevalence (Year / Location)	Status	
				Terai and inner Terai	**Hills/high hills**
		Fungal Diseases			
Foliar					
1.	Gray leaf Spot	*Cercospora zeae maydis* Tehon & Daniels	2006/ Dhungkharka, Kavrepalanchowk	Minor	Major
2.	Northern leaf blight	*Helminthosporium turcicum* Pass	1964/ Patan	Minor	Major
3.	Southern leaf blight	*Helminthosporium maydis* Nisik and Miyabe	1965/ Rampur	Major	Minor
4.	Banded leaf and Sheath Blight	*Rhizoctonia solani* (Kuhn)	1978/Rampur	Major	Major
5.	Common rust	*Puccinia sorghi* Schw.	1964/ Patan	Minor	Major
6.	Brown spot	*Physoderma maydis* Miyabe	1965/Gokarna	Minor	Major
7.	Leptosphaeria leaf blight	a. *Leptosphaeria zeae* Stout	1965/Ilam	Minor	Major
		b. *Leptosphaeria michotii* (West) Saco	1966/Kakani		
8.	Curvularia leaf spot	a. *Curvularia lunata* (Walker) Boedjn	1966/Godawari	Minor	Minor
		b. *C. geniculata* (Tracy and Sarle) Boedjn	1966/Kakani	Minor	Minor
		c. *C. pallescens* Boedjn	1967 /Kakan	Minor	Minor
		d. *C. leonensis* M.B. Ellis	1974/Rampur	Minor	Minor
9.	Anthracnose	*Colletotrichum graminicola* (Ces) Wilson	1965/Ilam	Minor	Minor
10.	Phyllosticta leaf spot	*Phyllosticta zeae* Stout	1965/Godawari	Minor	Minor
11.	Diplodia leaf spot	*Diplodia macrospora* Earle.	1966/Ilam	Minor	Minor
12.	Didymella leaf spot	*Didymella sp.*	1965/ Nakkhu	Minor	Minor
13.	Leaf spot	*Ascochyta zeae* Stout	1965/Khumaltar	Minor	Minor
14.	Leaf Spot	*Phaeosphaeria maydis*	1977/Kakani	Minor	Minor
15.	Leaf Spot	*Pithomyces chartarum* (Berk and Crut) MB Ellis	1964/Balaju	Minor	Minor
16.	Leaf spot	*Trichothecium roseum* (Pers) Link Ex.	1965/Ilam	Minor	Minor
17.	Leaf Spot	*Eudarluca austratis* Speg.	1964/Patan	Minor	Minor
18.	Mycosphaerella Leaf Spot	a. *Mycosphaerella zeicola* Stout	1966/ Rampur	Minor	Minor
		b. *Mycosphaerella sp*			

			1966/ Gokarna	Minor	Minor
19.	Leaf spot	*Phaeoseptoria sp.*	1974/Kakani	Minor	Minor
20.	Leaf spot	*Drechslera sp.*	1974/Kakani	Minor	Minor
21.	Leaf spot	*Phoma sorghina* Boerma, dorenbosoch and Vankent	1971/Kathmandu	Minor	Minor
22.	Leaf spot	*Pestalotiopsis sp.*	1971/Kathmandu	Minor	Minor
23.	Leaf spot	*Hendersonia culmicola* Sacc.	1971/Rampur	Minor	Minor
24.	Leaf spot	*Phoma insidiosa* Taasi	1970/Rampur	Minor	Minor
25.	Leaf spot	*Coniothyrium sp.*	1968/Parwanipur	Minor	Minor
26.	Leaf spot	*Pyrenochaeta indica* Viswanathan	1974/Kakani	Minor	Minor
27.	Leaf spot	*Aureobasidium pullulans* (Debary) Aranand.	1978/Rampur	Minor	Minor
Smut					
28.	Head smut	Sphacelotheca reiliana (Kuehn) Clinton	1966/Ilam	Minor	Major (Sporadic)
29.	Common smut	*Ustilago maydis* (D.C.) Corde	1971/Ilam	Minor	Major
30.	False smut	*Ustilaginoidea virens* (Cke) Tak.	1965/Parwanipur	Minor	Minor
Cob /Ear rot					
31.	Fusarium Kernel rot (Gray ear rot)	*Fusarium moniliforme* Sheld or *Gibberella fujikuro* (Saw) Wr.	1974/Kakani	Major	Major
32.	Fusarium ear rot/ Gibberella ear rot	*Fusarium graminearum* or *Gibberella zeae* (Saw) Petch.	1974/Kakani	Minor	Major
33.	Rhizoctonia ear rot	*Rhizoctonia zeae* Voorhees	1975/Pokhara	Major	Minor
34.	Diplodia ear rot	*Diplodia maydis (*Berk) Sacc.	1974/Kakani	Minor	Minor
35.	Gray ear rot	*Physalospora zeae* Stout.	1974/Kakani	Minor	Minor
36.	Cob rot	*Nigrospora oryzeae* (Berk and Berk) Petch.	1974/Kakani	Minor	Minor
37.	Ear rot	*Cephalosporium acremonium* Cda.	1974/Kakani	Minor	Minor
38.	Ear rot	*Aspergillus sp.*	1974/Kakani	Minor	Minor
39.	Ear rot	*Penicillium sp.*	1974/Kakani	Minor	Minor
40.	Ear rot	*Trichoderma viridae* Perx.ex. Fries	1976/Kakani	Minor	Minor
41.	Ear rot	*Helminthosporium sp.*	1976/Kakani	Minor	Minor
Stalk rots					
42.	Fusarium stalk rot	a. *Fusarium moniliforme* Scheld (*Gibberella fugikuroi* (Saw) Wr.) b. *Fusarium graminearum* Schw.	1971/Rampur	Minor	Minor

43.	Pythium stalk rot	*Pythium aphanidermatum* (Eds) Fitz.	1971/Kathmandu	Minor	Minor
44.	Diplodia stalk rot	*Diplodia maydis* (Berk) Sacc.	1971/Rampur	Minor	Minor
45.	Charcoal rot	*Macrophomina phasiolina* (Tassi) Goid	1974/Kakani	Minor	Minor
46.	Black-bundle disease	*Cephalosporium acremonium* Cda.	1970/Rampur	Minor	Minor
Downy mildews					
47.	Sorghum downy mildew	*Sclerospora sorghi* (Kulk) Weston and Uppal	1970/Rampur	Major (Sporadic)	Minor
48.	Philippine downy mildew	*Sclerospora*. *Philippinensis* Weston.	1967/Rampur	Major (Sporadic)	Minor
49.	Brown-strip downy mildew	*Sclerospora*. *rayssiae* ver. Zeae, Payak and Renfro.	1970/Rampur	Minor	Minor
Bacterial diseases					
50.	Bacterial stalk rot	*Erwinia carotovora* (Jones)	1968/Rampur	Major	Minor
51.	Bacterial leaf strip	*Xanthomonas rubrilineans*	1976/Rampur	Minor	Minor
52.	Stewart wilt	*Erwinia stewartii* (E.F. Smith Dye) Dowson.	1978/Rampur	Minor	Minor
Virus diseases					
53.	Leaf fleck	*Maize leaf fleck virus*	Rampur	Minor	Minor
54.	Mosaic	*Maize mosaic virus*	Rampur	Minor	Minor

METHODOLOGY

Explanation of the major maize diseases, their causal organisms, distribution, time and intensity of disease incidence, symptoms, survival, spreads, environmental factors for disease development, yield losses and various disease management strategies corresponded to important maize diseases of Nepal are collected and piled up thoroughly from the available publications. Results are summarized in tables, charts and texts with definite review of the important maize diseases and their management in Nepal.

Major fungal diseases

The majority of the maize diseases were foliar fungal diseases. Most of these diseases are distributed throughout the higher elevations of the mountains, hills and the terai. Some of the foliar diseases are favored by warm and humid conditions and others prevail in cool and humid conditions.

1. Gray Leaf Spot (GLS)

Gray leaf spot (GLS) disease caused by *Cercospora zeae maydis* Tehon & Daniels is a serious threat to farmers and has caused serious losses in grain yield of maize in 2006 (Manandhar *et al.,* 2011). The disease was first identified from the state of Illinois, USA in 1925 (Tehon & Daniels, 1925). Its occurrence was recorded in the Kavrepalanchowk district of Nepal (Manandhar, 2007). Grain yield losses of maize of up to 19 percent and 18 percent, respectively, on the local variety and on the improved OPV (Ganesh -1) were observed in field experiments (Manandhar and Baidya, 2010). The severity of GLS was high in the high hill region affecting adversely farmers who live with limited resources. The disease has been observed spreading over the years in 17 districts in the eastern, central and mid western regions of the country (Manandhar *et al*., 2009). GLS is evident on plants as small spots first on lower leaves of plants at tassel initiation. The disease moves upwards and spots change into long characteristics lesions within a month turning plants into a diseased field. The disease is significant since it rapidly destroys foliage when the plant is near at grain maturity (Manandhar *et al.*, 2011).

Management

Source of disease resistance

Genotypes of maize including Corpoica H-112, CLA 87/CLA 91 from Colombia, and ZM 627, ZM 525, 05 SADVI, 07 SADVI, ZM 401 and ZM 501 from Zimbabwe were identified as resistant to GLS (Manandhar *et al*., 2011). The OPVs like Ganesh-1, Deuti, Manakamana-1 and Manakamana-3 (Ganesh-1 for high hills), can reduce yield loss in GLS prone environments of the hills (Manandhar *et al*., 2011). Experiment conducted at Pakhribas, Dhankuta revealed that genotypes ZM-627, 02SADVIF2, ZM-401, 07SADVI, Ganesh-1 (ARSP), 05SADVI, Manakamana-3 (ARSP) and ZM-423 were moderately resistant again GLS (NMRP, 2012). Genotype 07SADVI was found highly resistant against GLS and produced 9.12t/ha grain yield and other moderately resistant genotypes were SOOTLWQ-B, RampurSO3FQ-02, Manakamana 6 and S01SIYQ at Pakhribas (NMRP, 2013). The results of screening nurseries conducted in summer season of 2013 from different locations of the country for GLS resistant and high yielding genotypes are presented in the table 2 (NMRP, 2014).

Cultural control

An experiment conducted at Khumaltar revealed that the incidence of GLS was found lower in early planting maize compared to late sown crops (PPD, 2007).

2. Northern Leaf Blight (NLB)

The causal organism of this disease is *Setosphaeria turcica* Luttrell (*Helminthosporium turcicum* (Pass) Leonard and Suggs). The pathogen first identified in the country in 1964 (Khadka and Shah, 1967; Manandhar, 1980; Dahal *et al.,* 1982). The disease is widely distributed throughout the country; however it is more prevalent in the cool and humid conditions of the foothills. It was not considered as the major disease of maize crop in Nepal until 1985. It is also common in the winter maize of the terai region. The disease usually

appears before tasseling and became the most important disease at present. Maize late sown in the season is most affected by this disease in hills (Manandhar *et al.,* 2007). The lesions of northern leaf blight can be observed together with other diseases on same or on different leaves of the plants. Greenish tan lens-shaped lesions on leaves are the characteristic symptoms of the disease. In the beginning, dark grayish green water-soaked oval areas appear on leaves. The disease is systematic in nature and lesions spread upward up to the top most leaves and sometimes the symptom is seen on the husk cover of ears. Lesions after coalescing each other cover a large area causing plants to dry and showing blighting appearance. Spores develop heavily in the middle of lesions with black velvet like appearance. Stalks of severely diseased plants become weak and they easily lodge. Hybrid genotypes of maize have also been affected by this disease in hills. Heavy losses could be incurred with a severe incidence of the disease. Severe infection has been already reported at Nijgadh, Bara during winter season maize at 2012 and also significant damage has been caused to the crop (NMRP, 2013).

Management

Source of disease resistance

Most of the maize genotypes so far tested was observed susceptible to moderately susceptible to the disease. However some genotypes have been found moderately resistant to the Northern leaf blight in different location during different year of experimentation (Table 3).

Table 2: GLS resistant and high yielding genotypes from different locations of the country during summer season of 2013

Locations	GLS resistant and high yielding genotypes
Dhumkharka, Kavrepalanchok	YML32/(P147-F2-134-S7/P33-C3-64-S5)-F2-B-7-3-1, YML58/(CML226/CATETO// CML226/ CATETO)F2-B-1-2-B, YML32/(P147-F2-108-S7/P45-C8-76-S5)-F2-B-30-1-3, YML32/Cel FSRYS9956-B-3-2-4-B, YML 58/(G34/36/G33TSR)-F2-B-3-1-B, YML 58/(G34/36/G33TSR)-F2-B-4-1-B, YML58/(SEY90-C1#/G34/36-B)-F2-B-2-1-B, Yunrui 505
Kapurkot, Salyan	YML23/P502-C2 -58-1-1-2-5-B, YML 23/P502-C2-185-3-4-1-3-B-1-B, YML23/P502-C3 -F2-10-8-1-1-B, YML 23 /GLSI01P502-B-25-2-B, YML23/P44-C10-HS8-30-2-2-1-B, YML23/P44-C10-HS8 -30-4-B-4-1- YML23/(MBR/MDR-C3W)-F44-2-2-1-B, B, YML23/GLSI01HGA
Subedi. 2015	YS12Q-189,
Suping, Makawanpur	RML-4/RML-17, RML-32/RML-17, GLSY, ZM-401, ZM-627
Pakhribas, Dhankuta	YML 23/P502-C2-185-3-4-1-3-B-1-B, YML 23 /GLSI01P502-B-25-2-B, YML23/P502-C2-58-1-1-2-5-B, YS12Q-189, YS 12Q-71, YML 23/GLS101HGA-B-4-1-B

Table3: Reaction of maize genotypes to NLB disease in different locations during different year of experimentation

Type	Location/Year/Season	Total test entries	Moderately resistant genotypes	Reference
Inbreds	Rampur/2004 -Winter	55	RL-47, RL-12, RL-31, CA00310, RL-57, CML-172, RL-16, CML-165, CML-164, CA 00314, CLQG-2509	Paudel *et al*., 2007
	Rampur/2005-Winter	240	RML-79, RML-80, RL-35A, RL-64, RL-34, RML-8, RL-75, RL-104	Paudel *et al*., 2007
	Rampur/2006-Winter	54	RML-36, RML-3, NML-1, RL-106, RL-57	Paudel *et al*., 2007
OPVs/Synthetic varieties	Rampur/2004 -Winter	32	SQGTLWQHGAB, SO3TLYQABO2	Paudel *et al*., 2007
Varietal screening trial	Rampur/ 2006-Winter	58	S99TLYQ-A, DRACON F1/DRACON F2, S99TLWQ-GHA, SOOTLYQ-B, CELAYA-S99551WQ, S99TLGHA, Deuti, AC9942 x AC9944, RamSO3FO6, RamSO3FO2, Shitala, SIS -IBP-UTYF	Paudel *et al*., 2007
F1 Hybrids	Rampur/ 2006-Winter	266	RL 111 x RL 189, RL 160 x RL 176, RL 128 x RL 169, RL 105 x RL 168, RL 130 X RL 169, RL 83 X RL 155, RL 82 X RL 150, RML 4 X RML 3, RML 3 X NML 2, RC X RL 12, RL 14 X RML 8, NML 2 X RL 12, RML 52 X RML 51, RML 6 X NML 2, RC X RML 17, RC X RML 3, NML 2 X RL 17, NML 1 X RML 8, RL 47 X RML 5, RML 6 X RML 8, RL 47 X RL 30 -1, RML 8 X RL 30-1, Bioseed 9681, RML 13 X Khumal Yellow, RML 52 X Khumal Yellow, RL 43 X Khumal Yellow, RML 59 X Khumal Yellow, RML 60 X Khumal Yellow, RL 28 X Khumal Yellow, RL 13 X Kumal Yellow, RL 190 X Khumal Yellow, RL 67 X Khumal Yellow	Paudel *et al*., 2007
OPVs	Pakhribas/(2003/2004-Summer)	20	Ganesh-1, Manakamana-3, ZM 621 (Deuti), Madi local white	Manandhar *et al*., 2007
	Rampur / (2003/04- Winter)	18	Ganesh-1, ZM 621 (Deuti), Banglore 9745, Hill Pool Yellow, Rampur Composite, Manakamana -3	Manandhar *et al*., 2007
	Lumle / (2003/04-Summer)	21	Population 44, Manakamana-3, ZM 621 (Deuti), Ganesh-1, Hill Pool White, Hill Pool Yellow, Ganesh-2, Manakamana-1 and PM-5	Manandhar *et al*., 2007
	Khumaltar / (2003/04-Summer)	18	Ganesh-1, ZM 621 (Deuti), Manakamana-3, Hill Pool Yellow, Hill Pool White, Banglore 9745,, Rampur Composite, Manakamana-1, Madi local white	Manandhar *et al*., 2007
Full season maize	Rampur /(2009-Winter)	21	RampurS03F04, RampurS03F02, S99TLYQ-B, RampurS03F08, TLBRSO7F16	NMRP, 2010
	Rampur /(2010-Winter)	24	RampurS03F02, S99TLYQ-B, RampurS03F08, BGBY population, Across 931, Takfa 0024	NMRP, 2011
Early maturing maize (OPV/Synthetic)	Rampur /(2009-Winter)	19	S02SADVIF2, EEYC1, S97TEYGHA8B (3), S01SYNZIME	NMRP, 2010
Genotypes	Rampur/ (2011-Winter)	32	PHRAPHUTTRBATS0031, TLRBSO7F16, SO19YNZIME, TLBR07F-14, BGBY-POP, COMPOZNIBP, RampurS03F02, R-POP 1, Upahar	NMRP, 2012
OPVS/Synthetic variety	Rampur/ (2012/13-Winter)	25	RML-105, BGBYPOP, Across 9942/9944	NMRP, 2013
OPVS/Synthetic variety	Rampur/ (2013/14-Winter)	25	RML-17, RML-96, RML-86, RML-19, RML-32/RML 17, RML-4/RML-17, RL-151/RL-111, 07SADVI, 05SADVI, ZM 627	NMRP, 2014

3 Southern Leaf Blight (SLB)

This disease caused by *Helminthosporium maydis* Nisik and Miye, is most common in the Terai region but is also found in some pockets of the mountains and the valleys. The disease usually appears at the time of tasseling. The perfect stage *Cochliobolus heterosporus* Dreschst is also recorded from Chitwan valley (Manandhar, 1983). Southern corn leaf blight occurs worldwide and important in regions of warm damp climate of 20-30 ^{0}C temperature (Agrios, 2005). A long dry period of sunny weather between rains is unfavorable to disease development. This disease reached epidemic proportion in 1970 in USA resulting in losses estimated at one billion dollars (Ullstrup, 1972). The epidemic was caused by Race T attacking corn with Texas male sterile cytoplasm (T cms) which comprises 85 % of corn acreage at that time. Race O occurs mainly in subtropical and tropical areas, where it causes minor losses. Yield reduction up to 50% was recorded (Fisher *et al*., 1976, Gregory *et al*., 1978). The disease has been occurring in terai, inner terai and mid hills (lower elevation) since many years in summer and winter maize in Nepal (Paudel and Koirala, 1995). The fungus remain over winter as mycelium and spores in maize debris in the field and race T on kernels in cribs, bins, elevators. The conidia are carried out by wind or splashing water to growing plants where primary infection occurs. Sporulation on the lesions produces additional primary or secondary inoculums. The disease cycle can be completed in about 60-72 hrs (Race T) under ideal conditions (Agrios, 2005).

Management

Source of disease resistance

From observation and experiences it has been found that early genotypes are more prone to Southern Leaf Blight disease as compared to full season varieties (Paudel *et al*., 2007). Efforts have been made to select SLB resistant genotypes and presented in table 4.

4 Banded leaf and sheath blight (BLSB)

The disease is caused by *Rhizoctonia solani* (Kuhn); its perfect stage is *Thanatephorus cucumeris* (Frank) Donk and mostly localized in the inner terai (Manandhar, 1983). The disease was first noted in 1977, and its incidence has been increasing in Nepal. Under natural conditions, disease appears at pre-flowering stage on 30 to 40 days old plants, but infection can also occur on young plants. The disease appears on basal leaf sheaths as water soaked, straw colored, irregular to roundish spot on both the surfaces. Profuse mycelia growth is seen on the affected areas of leaf sheath and in between the leaf sheath and stem. Later on as the infection becomes older, numerous sclerotial bodies develop on the affected parts (Agrios, 2005). The disease after its occurrence causes direct loss due to premature death, stalk breakage, destruction of leaves, leaf sheaths and ear rot. Banded leaf and sheath blight of maize is known under various names, viz; sclerotial disease, sharp eye spot, oriental leaf and sheath blight, Rhizoctonia ear rot, sheath rot and corn sheath blight etc (Rijal *et al*., 2007). It is a destructive plant pathogen with an almost unlimited host range. It aggressively colonizes organic debris and thus has enough saprophytic survival ability. No sexual spores are formed and only sclerotia formed as soil borne propagules. The sclerotia are knots of undifferentiated,

intertwined, pigmented monilioid cells. The symptoms of the disease are observed on all aerial parts of the plant except tassel. The disease manifests itself on leaf, leaf sheath, stalk and ears as leaf and sheath blight. Losses to the extent of 10-90% have been reported on different maize varieties /cultivars (Singh and Sarma, 1976; Butachaiah, 1977).

Management

Source of disease resistance

Out of several maize genotypes (inbreds/hybrids) screened against BLSB disease (table 5) under artificially inoculated conditions, very few genotypes showed resistant to moderately resistant reaction (Rijal *et al.*, 2007). Most of the susceptible genotypes were collapsed at the time of final disease scoring (Rijal *et al*., 2007).

Table 4: Reaction of maize genotypes to Southern Leaf Blight (SLB) in different locations during different year of experimentation

Type	Location/Year/Season	Total test entries	Moderately resistant genotypes	Reference
Inbreds	Rampur/2004 - Summer	20	CML 451, CA 00310, CA 00314, RL 5, RL 12	Paudel *et al*., 2007
	Rampur/2005-Summer	52	RML-18, RL-14, NML 1, RML-6, RL-30, RML-16, RML-18, RML-10, RL-12, RL-9, RML 55	Paudel *et al*., 2007
OPVs/Synthetic varieties	Rampur/2004 - Summer	19	Pop 45 C10, S99TLGAB (3), Pop44C10, Population 21, ZM 621, Cotaxla S9627	Paudel *et al*., 2007
	Rampur/2005 - Summer	28	SOISIYQ, Cotaxla S9627, Rampur So3 Fo4, SO3 TLYQAB-02, Narayani	Paudel *et al*., 2007
	Rampur/2006 - Summer	44	Sitala, Banglore 9745, Rampur So3 Fo2, Pop45 C10, Rampur So3 Fo8, Across 501, Takfa S9624, Takfa S9636, Rampur So3 Fo6, Rampur So3 Fo4, S99 TLYGHAB	Paudel *et al*., 2007
	Rampur/2009-Summer	28	Posilo Makai-1, Rampur So3 Fo6, TLBRS07F16 (R), RamS03F02, BLSBRS07F10	NMRP, 2010
	Rampur/2011-Summer	38	TLBRSO7F16, BLSBRS07F10, Across-9531, BGBYPOP, TLBRS07F14, RampurS03F08	NMRP, 2012
Genotypes	Rampur/2012-Summer	20	TPY, BLSBSO7F10, BLSBSO7F12, TLBRSO7F14, TLBRSO7F16, Across 9331 RE, HG-AB, RML-8/AC, Celaya 00HGYA/00HGYB, R-POP- 3, RML-4/NML-2, RML-32/RML-17, RML-4/RML 17	NMRP, 2013
	Rampur/2013-Summer	30	JH-1203, SYN312-SR, CML-444/CML-489, SYN 312-SR, CML-312/CML-444, CML-395/CML-444, CZH0838, CZH1108, ZH-1204, CML-305/CML 444	NMRP, 2014

Biological control

All the isolates of *Trichoderma* spp exhibited antagonistic activities against *R. solani* f. sp. Sasakii. The degree of antagonism in terms of inhibition of growth of mycelium, production, mass and viability of sclerotia of the pathogen was highly variable among the isolates. Among the seven isolates evaluated *Trichoderma Koeningii* TKB-1 exhibited maximum inhibition (51.5% (46.7%). Similarly *Trichoderma*

viridae –TVB-1 (76.9%) showed maximum reduction of sclerotia production. A complete reduction in the viability of sclerotia was recorded in case of THB-1 and TSB-67 (Batsa *et al*., 2004). Batsa *et al.*, (2004) studied about the comparative efficacy of cultural, chemical and biological control against BLSB in maize and found that the cost of BLSB control was minimum in leaf stripping however validamycin provided maximum (Rs 5.88) return from each rupee investment. Since BLSB spreads upward from the base of plants through sheath to sheath contact; leaf stripping breaks this contact restricting the upward movement of pathogen by 100 %. Hence Leaf stripping technique is also suggested for BLSB management in maize.

Table 5: List of different moderately resistant maize genotypes tested against BLSB in different locations and year.

Type	Location/Year/Season	Total test entries	Moderately resistant genotypes	Reference
Inbreds	Rampur/2006 - Summer	40	RML-8, RML-12, RL-84, RL-181, RL-155, RML-10, RL -28, RL-180, RL-140, RL-47, NML-2, RL-13, RML-41, RL-106	Rijal *et al*., 2007
Hybrids	Rampur/2006-Summer	19	AG 20 X AG 27, 108 X AG 27, 75 X AG 27, 114 X AG 27, 113 X AG-27, 103 X AG-27, 116 X AG-27, 69 X AG-27, 105 X AG-27	Rijal *et al*., 2007
Genotypes	Rampur/2009-Summer	63	RML-4, RML-5, RML-8, PUTU-13, AG-27, L-1, L-7, L-3	NMRP, 2010
	Rampur/2010-Summer	12	BLSBRS07F12, BLSBRS07F10, RML-8, Terai Pool Yellow	NMRP, 2011
	Rampur/2011-Summer	20	Synthetic-C, BGBYPOP, BLBRS07F10, HG-A, TLBRSO7F16, BG-B, R-Pop-3, R-Pop-4, SO3TLYQ-AB-02	NMRP, 2012
	Rampur/2012 - Summer	30	Terai Pool Yellow, TLBRSO7F16, HG A, R POP-4, Synthetic B, Synthetic C, Across 9331 RE, BGBYPOP, Arun-1 EV, Pool-17, 05SADVI, 07SADVI, GLSYW, RML-4/NML-2, RML-32/RML-17	NMRP, 2013
	Rampur/2013-Summer	30	DTM#-25, DTM#-27, DTM#-28, DTM#-30, DTM#-36, DTM#-37, DTM#-38, KEYPOP, KGPOP-2, KS 12 F12, 05 SADVI, 07 SADVI	NMRP, 2014
	Lumle/2013-Summer	30	DTM#-23, DTM#-35, DTM#-36, DTM#-32, DTM#-38, ZM 401, KGPOP-2, MHEY, KLYPOP	NMRP, 2014

5 *Ear rot*

The preliminary study of this disease was initiated in 1974-75. A number of pathogens have been observed in Nepal. Among the various ear rotting organisms, *Fusarium moniliforme* Schw. was found to the most common and most destructive to the crop (Manandhar, 1976). Pathogens like *Diplodia maydis* (Berk) Sacc. and *Rhizoctonia zeae* Voorhees were also common in the mountains but the infection was very low. Although Fusarium ear rot is distributed throughout the country, it is most prevalent in the mountains with cool and humid weather conditions (Manandhar, 1976). In these areas, the crop stands for 6-8 months in the field and the high rainfall provides favorable conditions for disease incidence. The infection rate in the mountain is usually 30-40% whereas in the inner terai and the Kathmandu valley it is only about 5-10% (Manandhar, 1983). In some varieties an intensity of infection of 80-90% has been reported. Such intensity of infection results in very high losses in grain yield. The improved varieties of maize seem to be more susceptible to this disease than some of the local varieties (Shah and Manandhar, 1978). *Fusarium graminearum* Schwabe (teleomorph

Gibberella zeae (Schw.) Petch, causes prominent *Gibberella* or red ear rot disease in high and mid hills. Red discoloration most common at tips of the ears and the husk leaves are recognizable symptoms of the disease at harvest. Severely affected ears are light and have tightly attached husk leaves. Numerous small black fruiting bodies of the fungus, a Gibberella state sometimes appear on husk covers or on other affected parts of the plant. The pathogen is common in injured areas caused by ear/kernel/silk-cut insects or birds and also on germinating kernels of the ears in lodged plants. Frequent rain or foggy weather prior to harvest enhances the ear rot disease and many high yielding maize varieties are susceptible to disease in high hills. The disease also appears later on harvested ears in high hills. Due to drying problem in high hills local maize is more popular among the farmers in spite of low grain yield or small size of the ears. The pathogen can also infect seeds/ seedlings/roots causing discolorations/rots/blights in field during germination in high hills. The incidence of ear rot was highest up to 40% in high hills like Kakani. It was moderate almost 20% in the eastern hills like Pakhribas and Kabre. Incidence of ear rot was in the range of 10% to 15% in the western hills at Jumla and Lumle, and lowest as below 5% at Khumaltar and in terai at Rampur (Manandhar and Gurung, 1982). The pathogen is also important for the quality of the maize since it can produce trichothecenes deoxynivalenol and nivalenol mycotoxin on moldy kernels. The occurrence of trichothecenes mycotoxins contamination was detected in 16% of 74 maize samples collected from different parts of Nepal (Desjardins *et al*., 2000).

Management

Source of disease resistance

Resistant genotype is the only ideal means to overcome the yield reduction due to the disease. Evaluation of maize genotypes for resistant to ear rot disease was initiated in NMRP, Rampur and presented in table 6.

Table 6: List of different moderately resistant maize genotypes tested against ear rot at Rampur in different year.

Type	Location/Year/Season	Total test entries	Moderately resistant genotypes	Reference
Genotypes	Rampur/2009-Summer	63	AG-27, RampurS03F02, RampurS03F04, RampurS03FQ2, BLSBRSO7F110, BLSBRS07F12, TLBRS07F14, TLBRS07F16, RPop-3, NML-1/NML-2 (Gaurav), RML-4/NML-2, RML-8/Rampur composite	NMRP, 2010
	Rampur/2010-Summer	12	Terai Pool Yellow, RampurS03F06, RML-8	NMRP, 2011
	Rampur/2011-Summer	20	Across 033, R-Pop-3, Synthetic-B, TLBRSO7F16	NMRP, 2012
	Rampur/2012-Summer	20	HG ‘A’, SO3TLYQ-AB-02, Synthetic-A	NMRP, 2013
	Rampur/2013-Summer	21	RML-98/RL-105, RML-68/RL-101, RML-8/RML-62, RL-197/NML-2, RL-180/RML-5, ZM-401	NMRP, 2014

6 Stalk rot

This group of diseases is broadly divided into two categories, namely pre-flowering and post-flowering types. The former category includes stalk rots such as Pythium stalk rot [*Pythium aphanidermatum* (Eds.) Fitzp.] and bacterial stalk rot [*Erwinia chrysanthemi* pv. *zeae* (Sabet) Victoria, Arboleda & Munoz], whereas others, such as Fusarium wilt, late wilt, black bundle disease and charcoal rot, appear in the post-flowering phase. Stalk rot is distributed throughout the country, but it is most prevalent in the hot and humid areas (Shah, 1968); however pythium stalk rot is found to be common in the mountains and the valleys in Nepal (Diwakar and Payak, 1975). The disease usually appears at the tasseling stage.

6.1 Pythium stalk rot

This stalk rot is known to cause extensive damage to the crop in the lowlands of northern India and southern Nepal. The incidence of disease is significantly influenced by both environmental and host factors. Temperature and relative humidity have been found to affect both the growth of the pathogen and disease development. The maximum disease development occurs within a temperature range of 30-35°C, with a relative humidity of 80-100%. Waterlogged, low-lying or poorly drained field conditions favor a high degree of disease development. Plant age (pre-flowering growth stage) and a large plant population (≥ 60000 per ha) favor a high incidence of disease (Diwakar and Payak, 1980).

Some resistant material has been identified. Hybrids Ganga Safed -2, Hi-starch, and composites Suwan 1 and Suwan 2, have shown resistance in India. An application of 75% captan (11 .2 g a.i. per 100 l water applied as a soil drench at the base of the plant when the crop is 5-7 weeks old) can check this disease effectively (Payak and Renfro, 1974).

6.2 Fusarium stalk rot

Stalk rots incited by *F. moniliforme* Sheld. and *F. graminearum* Schw. are known throughout Asia; however, the incidence of the former is more severe in lowland tropical areas, whereas the latter is present in the cooler highlands. The symptoms become conspicuous after flowering and towards maturity, when plants show premature drying. The pathogen commonly affects the roots, crown region and lower internodes. When split open, the stalks show a pink-purple discoloration with collapse of the pith region (De Leon, 1984). In old plants affected by *F. graminearum*, blue-purple ascomata of *Gibberella zeae* develop on the outer surface of the stalk rind. The diseases are known to occur in Nepal, India, Indonesia, Pakistan, Philippines, Thailand and Vietnam. They are observed more commonly if there is a period of drought during or shortly after pollination. Agronomically desirable stalk rot-resistant materials are available in Pakistan, India, Mexico and Zimbabwe, where selections against these diseases have been made. The 'stay green' character, in which plants remain green after attaining physiological maturity, has been associated with resistance to certain post-flowering stalk rots. There is evidence of mammalian toxicity where stalks infected with these pathogens

7 Head smut

Head smut caused by *Sporisorium reiliana* (Kuhn) Langdon & Full. (Syn. *Sphacelotheca reiliana* (Kuhn) Clinton or *Ustilago reiliana* Kuhn is a sporadic disease of maize in Nepal. Incidence of the smut disease was first recorded from Ilam in 1966 (Khadka and Shah, 1967). The disease is widespread in hilly regions of the country and is familiar among farmers because of its black sori often with phyllody or other abnormal symptoms in tassel and ears (Gurung *et al*., 1985). Generally the tassel or ears are completely or partially replaced by smut balls or leafy proliferations. The soil borne spores infect the plants during emergence or at the seedling stage and grow systematically with the meristem (Xu *et al*., 1999). The symptoms on the tassel often indicate presence of the smut pathogen in a maize field. Infected plants with normal tassels are also common. The ear in such plants can be seen smutted only at harvest. From time to time farmers have reported the smut problem in their fields. Head smut was noted on ears of variety Manakamana-1 at Pakhribas, Dhankuta in 1983. It also caused failure in seed production with the occurrence of the smut 30% and 10% respectively on varieties khumal yellow and Arun-2 during 1987 growing season (Manandhar, 1992). Incidence reached 75% on local maize 'Ashare' planted in February in Dhading during 1992. Ashare is harvested in June –July for maize-rice system at the foothills near Khanikhola. The smut incidence was reported as 100% on plants of some kitchen gardens grown for green ear consumption in Kathmandu Valley including Ramkot. Losses due to disease of 30% and above were reported in farmers field in epidemic years at Patlikhet village of Myagdi (Pradhananga and Ghimire, 1996; Ghimire and Harding, 1997). In Lalitpur, smut incidence up to 60 % was reported from Chunnikhel (W-7), Dhapakhel (W-3) and Thuladurlung (PPD, 2000). Farmers of Kulekhani asked remedies for smut problem. Its occurrence is reported mainly in hilly districts like Jumla, Kaski, Dolakha, Tehrathum, Sindhupalchwok and Nuwakot.

Management

1. Resistant cultivars: Sweet corn, Pop corn Hybrid B840 (Manandhar, 2002)
2. Seeding date: Smut incidence was noticed in decreasing trend with the highest percent in April or early May sown plants as compared to that sown in late May or June (Manandhar, 2002).
3. Seed treatment: Out of 15 fungicides, Sumi-8, Tilt-100, Raxil-2, Baytan-10 and Bayleton-5 have proved effective against the smut (Manandhar, 2002)

8 Common rust

This rust, caused by *Puccinia sorghi* Schw., develops on maize plantings in subtropical conditions in Nepal, Bhutan, South China and northern India. Aecial infection occurs infrequently on *Oxalis* spp. in Nepal. O. *corniculata* has been found to be susceptible under conditions of artificial inoculations with teliospores of *P. sorghi* in India. However aecial infections, so far, have not been observed in nature. Since the early 1970s in the state of Bihar, India, winter plantings have suffered epidemics of this rust, mainly because of the cultivation of the susceptible hybrids Ganga Safed-2 and Hi-starch (Sharma *et al*., 1993). In summer maize the incidence of the disease is quite high in the mountains and the valleys with very little disease incidence noted in the terai; however the disease has attacked the winter and spring maize of the terai in Nepal (Kashalappa and Hedge, 1970). The disease usually appears at the Knee-high stage or at tasseling. The local varieties of maize are highly susceptible to this disease which means that common rust existed in Nepal long before it was first reported in 1964 (Manandhar and Sah, 1972). Losses in grain yield ranging from 6 to 32% have been reported (Sharma *et al.,* 1982). The inheritance of generalized or mature plant resistance has been studied by Sharma and Payak

(1979) and has been established to be polygenic, with a small number of genes conditioning resistance. Cultivars possessing resistance are available in most countries. For seed production and susceptible cultivars of pop corn and sweet corn, two to three spray applications of the fungicide zineb are recommended.

9 Downy mildews

This group of pathogens constitutes one of the most important factors limiting maize production in South and South-East Asia. The important species causing downy mildew (DM) in maize in the region are the Philippine DM [*Peronosclerospora philippinensis* (Weston) Shaw], Sorghum DM [*P. sorghi* (Weston & Uppal) Shaw], Java DM [*(P. maydis* Raciborski) Shaw], Sugar-cane DM [*P. sacchari* (Miyabe) Shirai & Hara] and Brown stripe DM *(Sclerophthora rayssiae* var. *zeae* Payak and Renfro). It is most common in the warm and humid weather conditions of the Terai region (Shah, 1968). The infection rate is usually 10-20 % but when the weather is very wet and humid, the disease may become epidemic and the infection rate rise can to 30-60% (Manandhar, 1972). The disease appears when the plants are 3-4 weeks old. The losses incurred in heavy infection are 10-20% reduction in grain yield. Heavy infections have been most commonly observed in late sown (June-July) crops (Manandhar, 1975). The symptoms of the carry top like deformation has been observed in the inner terai since 1975. However the causal organism has yet not been established accurately (Manandhar, 1981).

9.1 *Philippine downy mildew*

This pathogen is widespread in the Philippines, plains of Nepal and northern India, Laos and northern Vietnam. The disease was first reported in India in 1912. This DM has also been found to possess the highest level of virulence: yield losses of 40-60% are frequent, and a disease incidence of 80-100% is not uncommon (Exconde, 1970). In Nepal, the disease developed in an epidemic form in 1987, with losses as high as 50%. It has been observed that late-sown plantings suffer greater damage (Shah and Tuladhar, 1971). Infection on maize is traceable to the proximity of infected clumps of the wild grass *Saccharum spontaneum.* The grass not only grows wild but also is planted as fencing around cultivated fields. Its eradication helps to eliminate this DM. Resistance in the Philippines is derived from indigenous open-pollinated varieties, particularly Tiniguib and Impa-Impa, others being Aroman White Flint, Kabacan WF, Bukidnon WF, Cadlan WF, Cebu WF, College WF and Bicol WF (Aday, 1975). The composites and varieties developed in the Philippines are based on crosses of local and introduced germplasm such as Tuxpeno, Eto Amarillo, Eto Blanco, Cupurico, Cuba Gr.l, and Tuxpantigua. A series of composites such as Phil DMR-l and DMR-5 have been released for cultivation.

9.2 *Sorghum downy mildew*

This pathogen was first recorded in teosinte *(Zea mays* ssp. *mexicana)* from Pune in 1905, and in 1907 on sorghum from India (Butler, 1907; Uppal and Desai, 1932). Since the 1960s, damage on maize and sorghum has been observed to have a cosmopolitan distribution. Three strains have been identified in *P. sorghi* -the sorghum strain (infecting only sorghum), the maize strain (attacking maize only) and a strain that infects both crops. In Thailand, only the maize strain of *P. sorghi* has been reported; in India, all three strains of the pathogen have been recorded (Payak *et al*., 1979). On the basis of isozyme analysis, Bonde *et al.* (1984) reported

that the Thai isolate has only four alleles out of 15 in common with those present in the five other isolates of *P. sorghi*. On the basis of isozyme analysis, the Thai isolate was more closely related to the *'P. sacchari-P. philippinensis* complex' than to *P. sorghi*. The fungus can inflict serious damage in introduced germplasm with no resistance. The DM-resistant cultivar Suwan 1, released in Thailand in 1973, spread rapidly throughout most Asian countries where it continues to show a good level of DM resistance. Selections of Suwan 1 have been released in Nepal, Bhutan, Burma, South China, India, Indonesia, Laos, Philippines, Sri Lanka and Vietnam. In Thailand, 80% of the area planted to maize has been covered by this high-yielding DM-resistant improved open-pollinated cultivar. Several CIMMYT maize populations (populations 22, 28, 31, 72, 75 and 78) have been selected by the CIMMYT-Asian Regional Maize Programme (CIMMYT, 1989); these combine desirable agronomic characters and a broader genetic base for DM resistance. Several other cultivars, such as Suwan 2 (early selection from Suwan 1) , Suwan 3, Nakorn Sawan 1 (NSI), Rampur 8075, and Ganga 11 (male parent Suwan 1) have been released by national programmes in Nepal, Thailand and India. In Thailand the agronomic practice of early planting in the rainy season is recommended for a low disease incidence. Late plantings are normally more damaged, mainly due to higher moisture and inoculum load.

9.*3 Brown stripe downy mildew*

This disease was first reported from India (Payak and Renfro, 1967). It has also been found in Burma, Nepal, Pakistan and Thailand (Frederiksen and Renfro, 1977), but is unknown outside South and South-East Asia. In the Himalayan area of northern India, the disease is limited to locations below 1500 msl (meters above sea level). Yield losses of up to 63% have been recorded in the *tarai* area of Uttar Pradesh (Sharma *et al*., 1993). As well as affecting maize, the disease has also been recorded on teosinte, *Digilaria sanguinalis,* in India and on D. *bicornis* in Thailand. Several cultivars possessing resistance to this DM have been identified. However, the most outstanding cultivar has been hybrid Ganga 5, widely grown in India. Genetic resistance to the disease has been identified with both additive and dominant gene actions. However, additive gene action plays a greater part in the expression of resistance (Asnani and Bhushan, 1970; Singh and Asnani, 1975). Late plantings (mid-July or later) suffer greater damage (Payak, 1980). Resistance to maize DMs in general has been determined to be polygenic (Mochizuki, 1975; Singburaudom and Renfro, 1982). An exception is sugar-cane DM in Taiwan where a resistance factor was also found to be monogenic and dominant (Chang, 1969). Several fungicides have been tried for the control of DM in maize. Seed treatment with Oemosan (chloroneb) was found to be promising against sorghum DM in Thailand (Titatarn, 1976) and in India, on brown stripe DM and sugar-cane DM in India (Lal, 1975) and on Java DM (Triharso and Kusdiarti, 1976). In the Philippines, economic returns for a schedule of three spray applications of Ou-ter (fentin hydroxide) followed by Dithane M 45 (mancozeb) was claimed to be cost effective and feasible for use against Philippine DM (Exconde *et al*., 1975). Among the systemic fungicides, acylalanines and the related compounds metalaxyl (Ridomil 25 WP, Apron 35 SO, Apron 30 FW), furalaxyl (Fongarid WP G), milfuram (Patafol, Caltan WP) and benalaxyl (Galben WP G) have been very effective in controlling DM incited by *Peronosclerospora* and *Sclerophlhora* (Venugopal and Safeeulla, 1978; Exconde and Molina, 1978; Lal *et al*.1980; Renfro, 1983).

10 Brown Spot

It is caused by *Physoderma maydis* Miyabe, the disease is widely distributed throughout the country. The disease usually appears at the time of tasseling. Severe incidences are found only in some parts of the inner terai and in Gulmi district. Losses have not been yet determined in Nepal. They have been reported non significant in India (Lal and Chakravarti, 1977). Normally the disease occurs in areas of abundant rainfall and high mean temperatures; it attacks the leaves, leaf sheaths, stalk and sometimes the outer husks. The first noticeable symptoms develop on leaf blades and consist of small chlorotic spots, arranged as alternate bands of diseased and healthy tissue. Spots on the mid ribs are circular and dark brown, while lesions on the laminae continue as chlorotic spots. Nodes and internodes also show brown lesions. In severe infections, these may coalesce and induce stalk rotting and lodging (CIMMYT Maize Program, 2004). Removal of plant debris and tillage operation minimizes the disease incidence in the maize field. Some tolerant maize varieties Manakamana-3, 4, 5 and 6 were released for the cultivation (Rijal, 2012).

Bacterial disease

Three bacterial diseases have been identified in Nepal.

1. Bacterial stalk rot

Bacterial stalk rot is caused by *Erwinia carotovora* and is generally confined to the terai. It is extended to some pockets of the mountains and Kathmandu valley but with very low rates of infection. The disease usually appears at the time of tasseling. Intensity of infection increases as weather conditions become warmer and humid (Manandhar, 1983). In the terai, the rate of stalk rot infection is high because 50% of the stalk rot is cause by corn borer damage and high percent of yield losses incurred. In the *tarai* area of northern India, and in southern Nepal and the southern Philippines, this disease represents a serious problem for maize production. It has been observed that a high disease incidence is associated with the use of sewage water for irrigation; it is particularly favoured by high temperatures (≥ 28°C) and high relative humidity, which prevails in most maize-growing areas 3-4 weeks after sowing. In India, resistance in some inbred lines, single crosses and hybrids has been identified through artificial inoculations. Among these, CM 104, CM 600, hybrids Ganga Safed-2 and multiple disease resistant (MDR) populations MDR-l and MDR-2 are known (Sharma *et al.*, 1993). This pathogen is highly sensitive to chlorine (Thind and Payak, 1972). Efficient control of the disease by using bleaching powder

($CaOCl_2$.H20 containing 33% chlorine), is achieved by drenching the basal stalk region when the plants are knee high.

2. Bacterial leaf strip

This disease caused by *Xanthomonas rubrilineans* was first reported by Manadhar in 1976. Its incidence has been extremely low. However in 1981 a severe infection appeared in epidemic form at Rampur, Chitwan (Manandhar, 1983).

3. Stewart Wilt

This disease caused by *Erwinia stewartii* (E.F. Smith Dye) Dowson has been reported from a few places in the terai. Because the incidence of the disease is very low, yield losses attributed to it are negligible (Manandhar, 1983).

Diseases caused by viruses

The viruses reported on maize in the Asian region are maize mosaic virus I, maize mosaic virus (MMV) and vein enation virus in India (Sharma and Payak, 1983), maize dwarf mosaic virus (MDMV), corn stripe and what is reported as 'leaf gall' (probably maize rough dwarf virus) in the Philippines (Exconde, 1983) and MDMV in China (Zhu *et al.*, 1983; Jingxiong, 1991). Incidences of virus diseases have been reported in Nepal, but none of the virus diseases have been unquestionably identified. The suspected virus diseases in Nepal are maize mosaic and leaf fleck (Manandhar, 1983).

Nematodes

Several nematodes have been found attacking maize. However, only the cyst nematode *(Heterodera zeae* Koshy, Swarup and Sethi) represents a serious problem in some maize growing areas (Koshy and Swarup, 1971). Carbofuran at 2 kg a.i. per ha is recommended for effective control. *H. zeae* can be managed by eradication of *Setaria* sp., an alternate host of the nematode, and by crop rotation (mainly by planting a non-susceptible crop).

Pathogenic variability study

Pathogenic variability observed among *F. graminearum* isolates from 3 cereal crops. Many virulent isolates were from maize. Out of 25, 4 including 3 from maize and 1 from rice were the most virulent isolates. There were 2 different groups in maize and isolates were able to cause disease on other crops. Both nivalenol and deoxynivalenol trichothecenes mycotoxins producing isolates were frequent and were able to cause disease (Manandhar *et al*., 2007).

Loss assessment study

Several maize diseases have been identified as economically important in national perspective (Khadka and Shah, 1967; Manandhar, 1983). Yield losses due to various diseases have been determined.

CONCLUSION

All the above mentioned diseases are destructive to the maize production in Nepal or worldwide due to the fact that they occur widespread in maize producing areas. It has been noted that maize diseases reviewed above results in severe economic losses and serves as a potential risk for humans and animals. Therefore, this review can provide sufficient information which will lead to development of management practices, and therefore improve maize production in the affected areas. Also, exploration and proper disease identification will be important to help to understand more about the diseases prior the intervention. Variability within pathogen should be considered for screening and breeding for resistance, or while testing sensitivity of the pathogen towards

different chemicals. An integrated approach using agronomic, nutritive, or chemical controls should be adopted for an effective disease management. Development of resistant varieties using conventional as well as biotechnological methods will help in controlling these menacing diseases which are still challenges even after several years of their discovery. Studies on epidemiology, diagnosis, yield loss and management of maize diseases (other than host resistance) seem to be quite behind and have to be focused. This review would be helpful to future on maize pathological research works in Nepal.

Table 7. Loss assessment study of important maize diseases in Nepal

Diseases	Loss assessment	References
Gray leaf spot	Grain yield loss up to 19 % in local variety	Manadhar and Baidya, 2010
Northern leaf blight	Reduced plant height (8%), grain yield (43%), Biomass (43 %) & 1000 grain weight (25%)	Duwadi, 1996
Common rust	Losses in grain yield 10-20%	Manandhar, 1983
Downy mildew	When the disease incidence was high the yield loss was estimated up to 10-20 %	Manandhar, 1983
Sclerotial ear rot	Loss in grain yield up to 42 % was found in cv. Rampur-2 at Rampur, Chitwan	Manandhar and Poudel, 1997
Fusarium ear rot	Grain yield loss up to 37% in cv Arun-4	Gurung, 1989
	Under Kakani the yield loss was recorded 21% & 6 % under Rampur	Manandhar *et al.*, 1978
Stalk rot complex	In a farmer's field at Chitwan about 80% grain yield loss was estimated	Batsa and Neupane, 1982

ACKNOWLEDGEMENTS

Thanks to maize Coordinator for continuous support and facilities. Plant Pathologists of NMRP and NARC are also acknowledged for their valuable suggestions.

REFERENCES

Aday, B. A. (1975). The Philippine program in breeding for resistance to downy mildew of maize. *Tropical Agricultural Research Service*, 8, 207-219

Agrios, G.N. (2005). *Plant pathology* . (5th ed.) Burlington, MA.: Elsevier Academic Press.

Asnani, V. L. & Bhushan, B. (1970). Inheritance study on the brown stripe downy mildew of maize. *Indian Phytopathology*, 23, 220-230.

Batsa, B.K. & Neupane, S.K. (1982). Loss assessment studies on stalk rot of maize. In: Proceedings of the 19th summer crop workshops pp. 99-101 at NMRP, Rampur, Chitwan, Nepal.

Batsa, B.K., Basnet, R., & Paudel, D.C. (2004). Biological control of banded leaf and sheath blight in maize. P.229. In: Proceedings of the 24th National Summer Crops Research Workshop on maize research and production in Nepal, June 28-30, 2004, Kathmandu, Nepal.

Batsa, B.K., Sharma, R.C., & Rai, S.N. (2004). Comparative efficacy of cultural, chemical and biological control against banded leaf and sheath blight in maize. P. 232. In: Proceedings of the 24th National Summer Crops Research Workshop on maize research and production in Nepal, June 28-30, 2004, Kathmandu, Nepal.

Bonde, M.R., Peterson, G.L., Dowler, W.M., & May, B. (1984). Isozyme analysis to differentiate species of *Peronosclerospora* causing downy mildews of maize. *Phytopathology,* 74, 1278-1283.

Butchaiah, K. (1977). Studies on some aspects of banded sclerotial disease of maize. Thesis M.Sc. (Ag.), G.B. Pant University of Agriculture and Technology, Pantanagar. 65 pp.

Butler, E. J. (1907). Some diseases of cereals caused by *Sclerospora graminicola. Mem. Dep. Agric., India, BOI. Ser.* 2, 1-24.

Chang, S.C. (1969). Genetic studies of resistance to downy mildews in corn by means of chromosomal translocations. *Rep. Corn Res. Taiwan* 7, 1-6.

CIMMYT Maize Program. (2004). *Maize Diseases: A guide for field identification*. 4th edition. Mexico, D.F. : CIMMYT. 2p.

CIMMYT. (1989). *Maize Research and Development in Pakistan.* CIMMYT, EI Batan, Mexico, 100 pp.

Dahal, G., Amatya, P., & Manadhar, H.K. (1992). Plant diseases in Nepal-country profile. *Review of Plant Pathology*, 71 (11), 797-807.

De Leon, C. (1984). *Maize Diseases, a Guide for Field Identification,* 3rd edn. CIMMYT, EI Batan, Mexico.

Desjardins, A.E., Manandhar, G., Plattner, R.D., Maragos, C.M., Shrestha, K., & McCormick, S.P. (2000). Occurrence of fusarium species and mycotoxins in Nepalese maize and wheat and the effect of traditional processing methods on mycotoxin levels. *Journal of Agriculture and Food Chemistry*, 48(4), 1377-1383.

Diwakar, M. C., & Payak, M.M. (1980) Influence of some environmental and host factors on Pythium stalk rot of maize. *Indian Phytopathology*. 33, 10—15

Diwakar, M.C., & Payak, M.M. (1975). Germplasm reaction to pythium stalk rot of maize *Indian Phytopathology*, 28(4), 548-549.

Duwadi, V.R. (1996). Northern leaf blight *Helminthosporium turcicum* tolerance lines screening of Manakamana -1. In: proceedings of summer crop workshops held in 27-29th Feb. 1996, at RARS, Parwanipur Bara, Nepal.

Exconde, O. R. & Molina, A. B., Jr. (1978). Note: Ridomil (CibaGeigy) a seed-dressing fungicide for the control of Philippine downy mildew. *Philipp.* 1. *Crop Sci.* 3, 60-64.

Exconde, O. R. (1983). Virus disease of maize in the Philippines. In: *Proc. Int. Maize Virus Disease Cotloqu. Workshop,* 2-6 *Aug. 1982, Ohio State Univ.* (Ed. by D. T. Gordon, J. K. Knoke, L. R. Nault and R. M. Ritter) pp. 203-205, Ohio Agricultural Research and Development Center. Wooster, Ohio.

Exconde, O. R., Raymundo, A. D., & Soriano, E. L., Jr. (1975). The economics of Duter/Dithane M-45 foliar spray for the control of Philippine corn downy mildew. *Philipp. Agric.* 59, 237-243.

Exconde. O. R. (1970). Philippine corn downy mildcw. *Indian Phytopathology,* 23, 275-284

Fisher, D.E., Hooker, A.L., Lim, S.M., & Smith, D.R. (1976). Leaf infection and yield loss caused by Helminthosporium leaf disease of corn. *Phytopathology*, 66, 942-944.

Frederiksen, R. A. & Renfro, B. L. (1977). Global status of maize downy mildew. *A. Rev. Phytopathology,* 15, 249-275.

Ghimire, S.R., & Harding, A.H. (1997) . Tilt-250: an effective fungicide to manage head smut Sphacelotheca reiliana (Kuhn) disease. LARC working paper no 97/35, Lumle Agricultural Research Centre, Pokhara, Kaski, Nepal.

Gregory, L.V., Ayers, J.E., & Nelson, R.R. (1978) . Predicting yield losses in corn from southern corn leaf blight. *Phytopathology*, 68, 571-581.

Gurung, G. (1989). Studies on cob rot fungi of maize. In: Proceedings of summer crops workshop held in 17-23 January, 1989 at ARS, Rampur, Chitwan, Nepal.

Gurung, G., Manandhar, K.L., & Batsa, B.K. (1985). Efficacy of fungicides against head smut of maize. Pp. 95-98. In: Proceedings of 12th Summer Crops Workshop held in Jan 28- Feb 1, 1985 at Rampur, Chitwan, Nepal .

Jingxiong, L. (1991). Maize growing under stress environment in China. In: *Proc. 4th Asian Regional Maize Workshop, 21-28 Sept. 1990, Pakistan* (Ed. by C. De Leon, G. Granados and M. D. Read) pp. 56-64, Kunming, Nanning.

Kashalappa, A.C.& Hedge, R.K. (1970). Studies on maize rust (*P. sorghi*) in Mysore state III: Prevalence and severity on maize varieties and impact on yield. *Plant Disease Report*, 54(9), 15-20.

Khadka, B.B., & Shah, S.M. (1967). Preliminary list of plant diseases recorded in Nepal. *Nepalese Journal of Agriculture*, 2, 47-76.

Koshy, P. K. & Swarup, G. (1971). Distribution of *Heterodera zeae, H. avenae, H. caiani and Anguina tritici* in India. *Indian Nematol. 4*, 106-111.

Lal, B.B. & Chakravarti, B.P. (1977). Resistance of maize varieties and lines to *Physoderma maydis* causal organisms of brown spot of maize in Udaipur. *Indian Plant Disease Report*, 61(2), 1080-1081.

Lal, S. (1975). Brown stripe and sugar -cane downy mildews of maize germplasm evaluation, resistance breeding and chemical control. *Trap. Agric. Res.* 8, 235-241.

Lal, S., Bhargava, S. K., & Saxena, S. C. (1980). Management of sugar-cane and brown stripe downy mildews in maize with metalaxyl. *Newslell. Int. Working Group Graminicolous Downy Mildews 2.*

Manandhar, G. & Poudel, D.C. (1997). Rhizoctonia ear rot disease and assessment of yield loss due to Rhizoctonia zeae. In: Proceedings of the 20th summer crop workshops pp. 209-215. National Maize Research Program, Rampur, Chitwan, Nepal.

Manandhar, G. (1992). Effect of fungicides to control head smut disease of maize. In: Proceedings of Summer Crops Workshop held in 26-31 January, 1992 at Rampur, Chitwan, Nepal.

Manandhar, G. (1997). *25 years of maize research in Nepal (1972- 1997)*. Nepal Agricultural Research Council, National Maize Research Program, Rampur, Chitwan, Nepal.

Manandhar, G. (2002). Head smut disease of maize in Nepal. Pp. 135- 141. In: N.P. Rajbhandari, J.K. Ransom, K. Adhikari, & A.F.E. Palmer (Eds). Sustainable maize production systems for Nepal: Proceedings of a maize symposium held in 3-5 December, 2001, NARC and CIMMYT, at Kathmandu, Nepal.

Manandhar, G. (2007). Gray leaf spot a threat to maize production in the hills of Nepal. *Quarterly newsletter of Nepal Agricultural Research Council*, 14 (4), 4.

Manandhar, G., & Baidya, S. (2010). Gray leaf spot of maize, a new disease to Nepal and loss assessment. In: Proceedings of the 26th National Summer Crops Workshop held in 3-5 March 2010 at National Maize Research Program, Rampur, Chitwan, Nepal.

Manandhar, G., Baidya, S., Bajracharya, A.R., Ferrara, G.O., and Tiwari, T.P. (2009). Maize gray leaf spot disease - a report presented in review and planning meeting at NARI,

Khumaltar, Nepal, organized by HMRP-III (NARC/DoA/SDC/CIMMYT) . 14-16 Dec. 2009. Manandhar, G., Baidya, S., Paudel, D.C., & Burlakoti, R.R. (2007). Evaluation of maize genotypes for resistant to northern leaf blight disease in Nepal. Pp. 273-275. In: D.B. Gurung, D.C. Paudel, G. KC, S.R. Upadhyay & B.B. Pokharel (Eds.). Proceedings of the 25th National Summer Crops Research Workshop on Maize Research and Production in Nepal, held in June 21-23, 2007 at Nepal Agriculture Research Institute, NARC, Khumaltar, Lalitpur, Nepal.

Manandhar, G., Desjardins, A.E., Manandhar, H.K., & Busman, M. (2007). *Fusarium graminearum*: an important pathogen of maize in Nepal, pathogenic variability and mycotoxins. Pp. 271-272. In: D.B. Gurung, D.C. Paudel, G. KC, S.R. Upadhyay & B.B. Pokharel (Eds.). Proceedings of the 25th National Summer Crops Research Workshop on Maize Research and Production in Nepal, held in June 21 -23, 2007 at Nepal Agriculture Research Institute, NARC, Khumaltar, Lalitpur, Nepal.

Manandhar, G., Ferrara, G.O., Tiwari, T.P., Baidya, S., Bajracharya, A.S.R., Khadgee, B.R., & Narro, L. (2011). Response of maize genotypes to gray leaf spot disease (*Cercospora zeae-maydis*) in the hills of Nepal. *Agronomy Journal of Nepal*, 2, 93-101.

Manandhar, K.L. & Shah, S.M. (1972). Screening of corn germplasm against leaf rust diseases under Kakani condition. In: Proceedings of Inter-Asian corn improvement workshop, Bangkok, Thailand.

Manandhar, K.L. (1972). Study on downy mildew disease of maize under Rampur condition. In: Proceedings of Maize seminar held in June 20-22, 1972 held at Department of Agricultural Education and Research Kathmandu, Nepal.

Manandhar, K.L. (1975). Second supplementary list of plant disease in Nepal. *FAO Bulletin technical Document* No. 97.

Manandhar, K.L. (1976). Preliminary studies of cob tot disease of maize in Nepal. *Nepalese Journal of Agriculture*, 6, 11.

Manandhar, K.L. (1980). Review on maize diseases investigation from 1975-1980. In: Proceedings of the 8th Summer Crops Workshop held at 25-30 January 1980. National Maize Development Program, Rampur, Chitwan, Nepal.

Manandhar, K.L. (1981). Review of maize disease investigation from 1976-1980. In: Proceedings of 8th summer crop workshop held in 25-30 January 1980 at National Maize Development Program, Rampur, Chitwan, Nepal.

Manandhar, K.L. (1983). Investigation of maize diseases in Nepal - I: Identification and prevalence. *Journal of Institute of Agriculture and Animal Science*, 4, 45-56.

Manandhar, K.L., & Gurung, G. (1982). Report on the screening of maize varieties against stalk rot, cob rot and common rust of maize. Pp. 107-114. In: Proceedings of the 9th Summer Crops Workshops HMG, Ministry of Food, Agriculture and Irrigation, Department of Agriculture held in 25-29 January, 1982 at Parwanipur Agriculture Station, Parwanipur, Bara, Nepal.

MOAD. (2014). *Statistical information on Nepalese agriculture 2070/71*. Agri-business Promotion and Statistics Division. Ministry of Agriculture Development, Kathmandu, Nepal.

Mochizuki, N. (1975). Inheritance of host resistance to downy mildew disease of maize. *Trap. Agric. Res.* 8, 179-193.

NMRP. (2010). *Annual Report 2066/67 (2009/10)*. National Maize Research Program, NARC, Rampur, Chitwan, Nepal.

NMRP. (2011). *Annual Report 2067/68 (2010/11)*. National Maize Research Program, NARC, Rampur, Chitwan, Nepal.

NMRP. (2012). *Annual Report 2068/69 (2011/12)*. National Maize Research Program, NARC, Rampur, Chitwan, Nepal.

NMRP. (2013). *Annual Report 2069/70 (2012/13)*. National Maize Research Program, NARC, Rampur, Chitwan, Nepal.

NMRP. (2014). *Annual Report 2070/71 (2013/14)*. National Maize Research Program, NARC, Rampur, Chitwan, Nepal.

Paudel, D.C., & Koirala, K.B. (1995). Pathological report on breeding trial and nurseries (1992-1994). 15p. In: Proceedings of the 18th Summer Crops Workshop held in 1-2 March 1995 at National Maize Research Program, Rampur, Chitwan, Nepal.

Paudel, D.C., Rijal, T.R., & Tripathi, N. (2007) . Tolerance and resistance of maize genotypes against southern leaf blight disease. Pp. 256-262. In: D.B. Gurung, D.C. Paudel, G. KC, S.R. Upadhyay & B.B. Pokharel (Eds.). Proceedings of the 25th National Summer Crops Research Workshop on Maize Research and Production in Nepal, held in June 21-23, 2007 at Nepal Agriculture Research Institute, NARC, Khumaltar, Lalitpur, Nepal.

Paudel, D.C., Tripathi, N., & Rijal, T.R. (2007) . Tolerance and resistance of maize genotypes against northern leaf blight disease. Pp. 247-255. In: D.B. Gurung, D.C. Paudel, G. KC, S.R. Upadhyay & B.B. Pokharel (Eds.). Proceedings of the 25th National Summer Crops Research Workshop on Maize Research and Production in Nepal, held in June 21-23, 2007 at Nepal Agriculture Research Institute, NARC, Khumaltar, Lalitpur, Nepal.

Payak, M. M. (1980). Management of graminaceous downy mildews - a blueprint. In: *Strategies for Control of Graminaceous Downy Mildew* (Ed. by R. D. Durbin. R. A. Frederiksen, A. Kelman & B. L. Renfro) pp. 183-191, The Rockefeller Foundation, New York, USA.

Payak, M. M., & Renfro, B.L. (1974). A decade of research on maize diseases: impact on production and its international cooperative outreach. In: *Current Trends ill Plant Pathology* (Ed. by S. P. Rychaudhuri and J. P. Verma) pp. 160--170, Department of Botany, Lucknow University. India.

Payak, M. M., Sharma, R. C., & Menon, K. (1979). Sorghum downy mildew of maize - physiologic specialization and resistant sources. In: *Revista De La Facllitad De Agronomica*, pp. 177-187 . Universidad Central De Venezuela, Maracay, Venezuela.

Payak, M.M. & Renfro, B. L. (1967). A new downy mildew disease of maize. *Phytopathology*, 57, 394-397.

PPD. (2000). *Annual report 2055/56 (1998/99)*. Plant Pathology Division, Nepal Agricultural Research Council, Lalitpur, Nepal.

PPD. (2009). *Annual report 2064/65 (2007/08)*. Plant Pathology Division, Nepal Agricultural Research Council, Lalitpur, Nepal.

Pradhanang, P.M., & Ghimire, S.R. (1996). Fungicides management of maize head smut (Sphacelotheca reiliana) by seed treatment. *Tropical Agricultural (Trinidad),* 73(4), 325-328.

Renfro, B. L. (1983). The occurrence and control of downy mildew of maize in Asia. *Newlell. Int. Working Group Graminicolous Downy Mildews,* 5.

Rijal, T.R. (2012). Makibalima Lagne Mukhya Mukhya Rogharu Tatha Rokthamka Upayaharu (Main diseases of maize and preventive methodologies). *Hamro Sampada National Monthly*, Kathmandu, Nepal, 4, 48-55.

Rijal, T.R., Paudel, D.C., & Tripathi, N. (2007) . Screening of maize inbreds/hybrids against banded leaf and sheath blight disease. Pp. 268-270. In: D.B. Gurung, D.C. Paudel, G. KC, S.R. Upadhyay & B.B. Pokharel (Eds.). Proceedings of the 25th National Summer Crops Research Workshop on Maize Research and Production in Nepal, held in June 21-23, 2007 at Nepal Agriculture Research Institute, NARC, Khumaltar, Lalitpur, Nepal.

Shah, M. & Tuladhar, K. L. (1971). Downy mildew diseases of maize in Nepal. *Proceedings of 7th Inter Asian Corn Improvement Workshop, Los Banos, Philippines,* pp. 88-94, Inter-Asian Corn Program, Kasetsart University, Bangkok.

Shah, S.M. (1968). Diseases of maize in Nepal. In: Fifth Inter-Asian corn improvement workshop, Department of agriculture and Kesetsart University, Bangkok, Thailand.

Shah, S.M., & Manandhar, K.L. (1978). A review of corn disease investigation in Nepal (1967-1977). Pp. 144-159. In: Fourth National Maize Development Workshop, HMG, Ministry of Food, Agriculture and Irrigation, Department of Agriculture held in 9-13 July, 1978 at National Maize Development Program, Rampur Nepal.

Sharma, R. C. & Payak, M. M. (1979). Resistance to common rust of maize in India. *Maize Genetic Cooperation Newsletter* 53, 65-66

Sharma, R. C. & Payak, M. M. (1983). An overview of virus and virus-like diseases of maize in India. In : *Proc. Int . Maize VirusDisease Colloqu. Workshop.* 2-6 *Aug. 1982. Ohio State Univ*. (Ed. by D. T. Gordon. J. K. Knoke . L. R. Nault and R. M. Ritter) pp. 186-190. Ohio Agricultural Research and Development Center. Wooster. Ohio.

Sharma, R. C., Payak, M. M., Shankarlingam, S., & Laxminarayan, C. (1982). A comparison of two methods of estimating yield losses in maize caused by common rust of maize. *Indian Phytopathology 35,* 18-20.

Sharma, R.C., De leon, Carlos., & Payak, M.M. (1993). Diseases of maize in South and South-East Asia: problems and progress. Crop Protection, 12(6), 414-422.

Singburaudom, N. & Renfro, B. L. (1982) . Heritability of resistance in maize to sorghum downy mildew *(Peronoscferopora sorghi* (Weston and Uppal) C. G. Shaw). *Crop Prot.* I, 323-332.

Singh, B.M., & Sharma, Y.R. (1976). Evaluation of maize germplasm to banded disease and assessment of yield loss. *Indian Phytopathology*, 19, 129-132.

Singh, I. S. & Asnani, V. L. (1975). Combining ability for resistance to brown stripe downy mildew in maize. *Indian J. Genet. Plant Breed.* 35, 128-130.

Tehon, L.R., & Daniels, E.Y. (1925). Notes on the parasitic fungi of Illinois. *Mycologia*, 17, 240-249.

Thind, B. S. & Payak, M. M. (1972). Antibiotics and bleaching powder in the control of bacterial stalk rot of maize. *Hindustan Antibiotics Bull.* 15, 9-13.

Titatarn, S. (1976). Report on experiments to control corn downy mildew in Thailand. *Kasetsart J.* 10, 111-115.

Triharso, T. & Kusdiarti, L. (1976). Recent problems and studies on downy mildew of maize in Indonesia. *Kasetsart J.* 10, 101-105.

Ullustrup, A.J., (1972). The impacts of the southern corn leaf blight epidemics of 1970/71. *Annual Review of Phytopathology*, 10, 37-50.

Uppal, B. N. & Desai, M. K. (1932). Two new hosts of the downy mildew of sorghum in Bombay. *Phytopathology*, 22, 587-594.

Venugopal, M. N. & Safeeulla, K. M. (1978). Chemical control of the downy mildews of pearl millet. sorghum and maize. *Indian J. Agric. Sci.* 48, 537-539.

Xu, M.L., Melchinger, A.E.,& Lubberstedt, T. (1999) . Species specific detection of the maize pathogen Sphacelotheca reiliana and Ustilago maydis by dot hybridization and PCR-based assays. *Plant Disease*, 83 (4), 390-395.

Zhu, F. C., Chen, Y. T., Zhang, H. F.,& Tsai, J. H. (1983) . Identification, transmission, host range and epidemiology of maize dwarf mosaic virus in North-western China. In: *Proc. Int. Maize Virus Disease Colloqu. Workshop.* 2-6 *Aug 1982. Ohio State Univ.* (Ed. by D. T. Gordon, J. K. Knoke . L. R. Nault and R. M. Ritter). pp. 194-202, Ohio Agricultural Research and Development Center, Wooster. Ohio

Journal of Maize Research and Development (2015) 1(1):53-63

ISSN: 2467-9305 (Online)/ 2467-9291 (Print)

DOI: 10.5281/zenodo.34293

Assessment of maize stem borer damage on hybrid maize varieties in Chitwan, Nepal

Buddhi Bahadur Achhami[1*], Santa Bahadur BK[1] and Ghana Shyam Bhandari[1]

ARTICLE INFO

Article history:
Received:
27th April 2015
Revised:
25th June 2015
Accepted:
16th October 2015

Keywords:
Hybrid maize stem borer, damage parameters, yield attributes

ABSTRACT

Maize is the second most important cereal crop in Nepal. However, national figure of grain production still remains below than the world's average grain production per unit area. Thus, this experiment was designed to determine the suitable time of maize planting, and to assess the peak period of one of the major insects, maize stem borer, in Chitwan condition. The results showed that plant damage percentage as per the maize planting month varies significantly, and the average plant damage percentage by stem borer was up to 18.11%. Length of the feeding tunnel in maize stem was significantly higher in January than July. In case of exit holes made by borer counted more than four holes per plant that were planted in the month of January. All in all, except the tunnel length measurement per plant, we observed similar pattern in other borer damage parameters such as exit whole counts and plant damage percentage within the tested varieties. Stem borer damage was not significantly affect on grain yield.

INTRODUCTION

In spite of diverse cultivation areas and seasons of maize, *Zea mays* L, in Nepal, the productivity maize is 2.3 ton/ha (MoAD, 2013); both biotic and abiotic constraints have played a major role in limiting grain production per unit area as compared to other developed nations. Among the biotic factors, maize stem borer complex is one of the most important insects in maize field (Neupane, Chapman, & Coppel, 1984; Jyoti & Shivakoti, 1992; Sharma & Gautam, 2010). About 20 to 80% of plants damaged due to maize stem borer were recorded in various studies (Thakur, Shrestha, Bhandari, & Achhami, 2013; Neupane, Coppel, & Chapman, 1984a). Similarly, Sharma & Gautam (2010) recorded more than 28% of grain harvested from stem borer protected field as compared to borer unprotected field. Mainly, the borer complex associated species in Chitwan condition were *Chilo partellus*, *Sesamia inferens*, *Chilo suppersalis* (Jyoti & Shivakoti, 1992). Female stem borer lay eggs in the leaves of both host and non-host plants. Newly hatched larvae migrate to search for host leaf and started to feed on the leaf that was enclose in whorl or was not fully exposed leaf. As a result of the leaf damage remarkable symmetrical holes are visible

Corresponding author Info:
**Technical Officer (Entomology),*
1.National Maize Research Program,Rampur, Chitwan, Nepal E-mail- buddhiachhami@gmail.com

once the leaf fully exposed. Similarly, depends upon the size of the hole made by larvae on leaves, the damages are categorized as pin hole and window panes, the small (=pin head size) and large size hole (=larger than pin head to tends to leaf tearing). After having leaf damage, the larvae move inside the collar region of the plant, and started feeding on stem leading to develop a feeding tunnel. After feeding, some larvae pupate inside the stem while others migrate out of the stem. The objective of larval migration, by making a circular hole on the stem, from the stem is to become a pupa. Roughly, up to five generations of *C. partellus* recorded in the Chitwan valley of Nepal (Neupane, Chapman, & Coppel, 1986). Various biotic and abiotic factors including micro-climatic and edaphic factors play significant role in overall production of maize. In Chitwan, the month of June and July the maximum temperature is increased by 0.03^{0}C to 0.04^{0}C per year (Nayava & Gurung, 2010).In this slow but gradual changing scenario of temperature, crop cycles tend to shift from its original cycle. Consequently, many studies reported that changing cropping pattern as well as crop cycle and associated insect pest biology is shifting accordingly (Malla, 2008; Nayava & Gurung, 2012; Paudel, Acharya, Ghimire, Dahal & Bista, 2014). Thus, we may need to manipulate our crops and cropping pattern to mitigate the possible consequences of changing scenario of climates and insect-pest biology.Thus, objectives of the study are, 1) to find the best planting time for hybrid maize varieties; 2) to determine peak activities of maize stem borer in hybrid maize varieties in Chitwan condition.

MATERIALS AND METHOD

Plant materials: The research was carried-out at the research farm of National Maize Research Program, Rampur, Chitwan, Nepal. The geography of the experimental site is latitude 27^{0} 40’N and longitude 84^{0} 19’ E, and 228 m mean sea level. At field, four maize genotypes, two hybrids: RML32/RML17 and RML4/RML17 and two open pollinated varieties: Across 9942/Across9944 and S99TLYQ-B were planted at every Wednesday from July, 2012 to July 2014. For each genotype, two rows of five meter long, and the crop geometry 75×25cm were maintained. All the agronomic practices such as fertilizer application, weeding, side-dressing, and other necessary management practices were done as per the standard protocol to grow a good crop stand except any application of plant protection measure.

Data collection: Plant damage percentage, stem tunneling, exit hole count, number of kernel rows, number kernels per row, cob diameter, and grain yield were taken from the tested varieties and each date of planting. However, we have included only two hybrid varieties: RML32/RML17, and RML4/RML17, was considered for the following result.

Plant sampling: For exit hole and tunnel length measurement, five plants from each tested variety and each date of planting were collected. Similarly, five cobs from each date of planting and each tested variety were taken to measure cob diameter, number of kernel rows, kernels rows per row, and cob diameter.

Plant damage parameters: Plant damage percentage was assessed during the vegetative stage just before tasselling stage visually by counting healthy and damage plants of all tested varieties and each date of planting. However, the exit holes made by stem borer from the five sampled plants were counted visually after removing the intact leaves on stem, and then proceed for tunnel length measurement. Thereafter, the sampled plants were dissects longitudinally, and then measure the groove made by stem borer by using simple measuring scale in centimeter.

Yield attributes: Cob diameter, number of kernel per row, and number of kernels rows per cob were measured after harvesting five sample cobs from each date of planting and each tested varieties. For cob diameter was performed by using Vernier caliper, and counting the kernel rows and number of kernels per row by shelling individual cob each count. In case of grain yield estimation, we harvested all cobs and converted it into ton per hectare by using the formula: field weight (kg) × (100- moisture content) × (10,000 × 0.8)/ (net plot area × shelling percentage × 1000)

Data analysis: All the collected data were analyzed by using statistical software R.3.2. Analysis of variance, regression analysis and clustering of maize planting months according to borer damage parameters, and yield attributes.

RESULTS

1) *Plant damage percentage*

The Plant damage percentage is presented in Figure 1 and Table 1. The highest plant damage percentage (22%) caused by maize stem borer was recorded in the maize planting month of June followed February and March. The lowest damage percentage was recorded in the planting month of October. Within the tested varieties, year of planting, and interactions among these factors were not found significantly differences in case of plant damage percentage (data not shown).

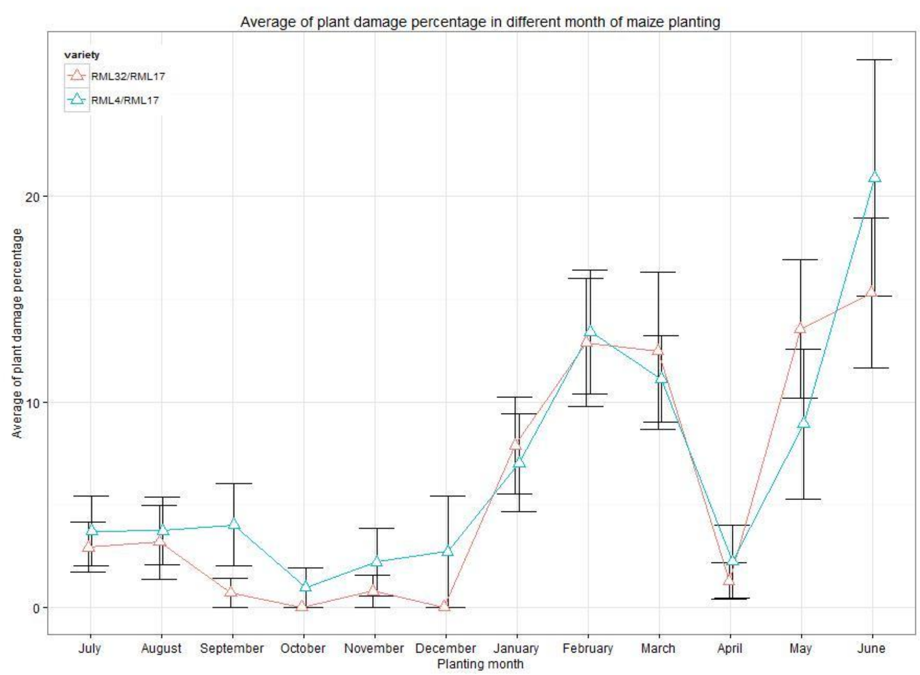


Figure1: Average of plant damage percentage with error bar in different month of maize planting in two varieties. The average is calculated based on data from two year of observations.

2) Tunnel length measurement

Average of stem tunneling caused by maize stem borer was measured in centimeter. The expression of measured length represented in figure 2 and table 1. The highest (16.82 cm per plant) in the plant that were planted in the month of January. And the lowest (0.94 cm per plant) measurement was recorded those plants which were planted in the month of June. Similarly, the second year (2013/14) of planting was relatively higher stem tunneling per plant than first year (2012/13), and RML32/ RML17 was more susceptible to stem damage than the RML4/RML17.

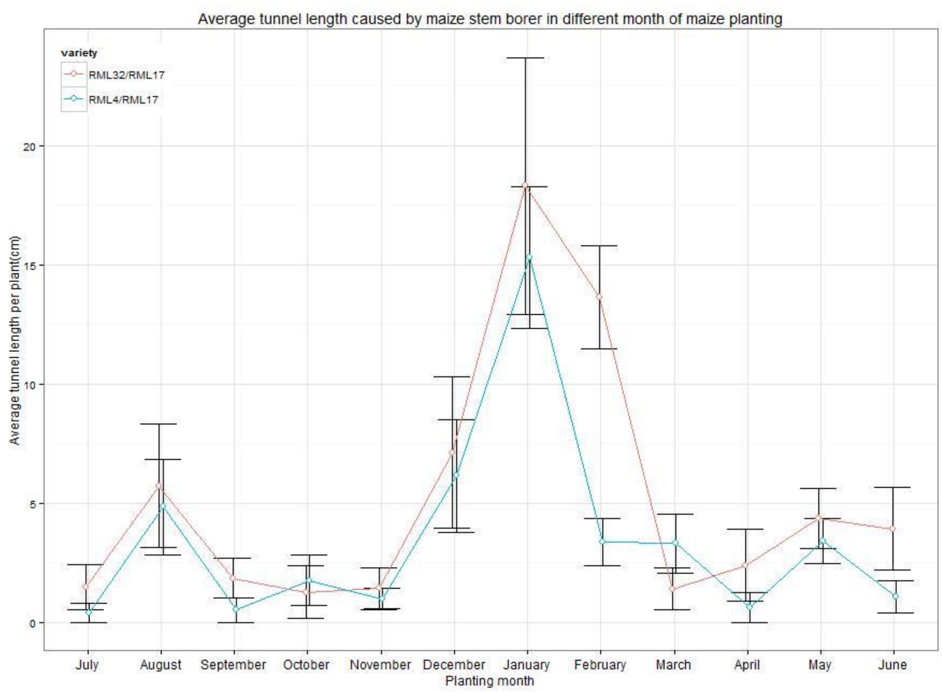


Figure 2: Average of tunnel length measurement (in centimeter) with error bar in different month of maize planting. The average is calculated based on data from two year of observations.

3) Exit hole counts

Plants that were planted in January and February had the highest average number (5.4 holes) of exit holes per plant as compared to rest of the planting months of maize (figure 3 and table 1). Within the tested varieties and year of maize planting, and their interactions were not found significantly different in terms of number of exit holes counted per plant (data not shown).

Table 1: Mean of stem borer damage parameters and yield attribute traits. Data represents mean of two hybrid varieties (RML4/RML17 and RML32/RML17), and over two years period

Planting month	Stem borer damage parameters			Yield components			
	Tunnel length per plant (cm)	**Exit hole per plant**	**Plant damage percentage**	**Number of kernel row**	**Cob diameter (cm)**	**Number of kernels per row**	**Grain yield kg ha^{-1}**
January	16.83 ^{a}	4.16 ^{a}	7.45 ^{cd}	12.95^{b}	4.36^{a}	33.34^{ab}	5050.11^{abcd}
February	8.51 ^{b}	5.42^{ab}	13.15 ^{ab}	12.67^{b}	4.29^{a}	36.39^{a}	6045.20^{ab}
March	2.36 ^{bc}	0.84^{bc}	11.80 ^{bc}	13.36^{a}	4.37^{a}	35.97^{a}	6264.16^{ab}
April	1.51 ^{bcd}	0.60^{c}	1.75 ^{e}	20.08^{b}	4.18^{a}	26.80^{bc}	5836.21^{abc}
May	3.89 ^{cde}	1.91^{bc}	11.23 ^{bc}	21.88^{a}	4.05^{a}	24.59^{c}	4869.14^{abcd}
June	3.04 ^{de}	1.28^{bc}	19.00 ^{a}	23.38^{a}	4.05^{a}	23.45^{c}	4748.64^{abcd}
July	0.94 ^{de}	0.31^{c}	3.32 ^{de}	13.01^{b}	4.07^{a}	34.79^{a}	6471.44^{a}
August	5.28 ^{de}	0.55^{c}	3.45 ^{de}	12.79^{b}	4.22^{a}	33.69^{ab}	5812.84^{abc}
September	1.18 ^{de}	0.30^{c}	2.35 ^{de}	12.63^{b}	4.37^{a}	29.15^{abc}	6776.35^{a}
October	1.51 ^{de}	0.17^{c}	0.48 ^{e}	12.36^{b}	4.32^{a}	26.98^{bc}	3733.02^{d}
November	1.21 ^{de}	0.33^{c}	1.50 ^{e}	12.69^{b}	4.18^{a}	24.81^{c}	3878.69^{cd}
December	6.64 ^{e}	1.06^{bc}	1.36 ^{e}	12.58^{b}	4.16^{a}	30.03^{abc}	4451.50^{bcd}
Year	**	ns	ns	**	*	*	*
Planting month	**	**	**	**	ns	*	*
Variety	*	ns	ns	ns	*	ns	ns

(*P < 0.05; **P < 0.01; ns: not significant) Means with same letter are not significantly different at 0.05 level of significance

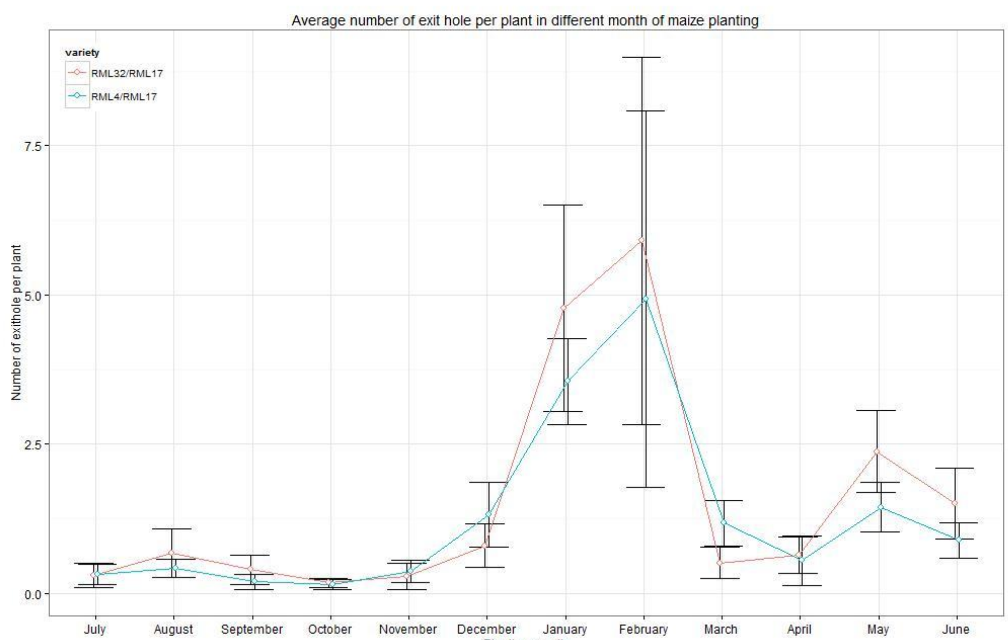


Figure 3: Average number of exit hole with error bars different month of maize planting. The average is calculated based on data from two year of observations.

4) ***Clustering of borer damage parameters and yield traits***

Percent plant damage, tunnel length, and exit holes were categorized as stem borer damage parameters. By considering these parameters, we made a dendorgram according to the planting months of maize (fig 4a). The borer damage parameters were similar in August, September, October, July and November. Similarly, February, March and May were in one category; while the month of June and January each has made a separate cluster clusters based on borer damage parameters.

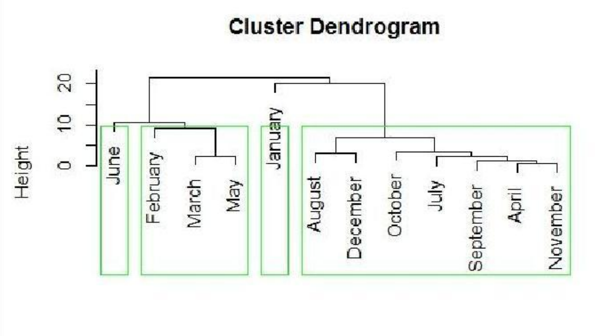


Figure 4a: Clustering pattern of stem borer damage parameters: plant damage percentage, tunnel length measurement per plant and exit holes counts per plant in tested genotypes

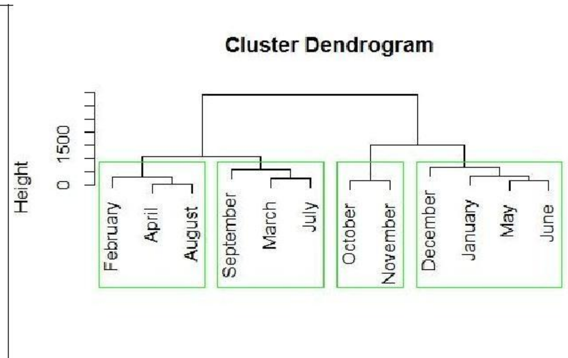


Figure 4b: Clustering pattern of yield attribute traits: cob diameter, cob length, number of kernels per row and number of kernel rows per cob in tested genotypes

The figure 4b represented the yield attribute traits, which were included plant height, number of kernel rows per cob, kernels numbers per row. According to the cluster dendrogram, there are four categories of maize planting months. February, April and August in one group; September, March and July in second group; October and November in third group; and December, January, May and June are in the fourth category.

All the observed damage parameters of maize stem borers had not exert a significant impact on grain yield of both tested varieties; however, cob length and number of kernels per cob had a significant positive role for grain production (figure 5).

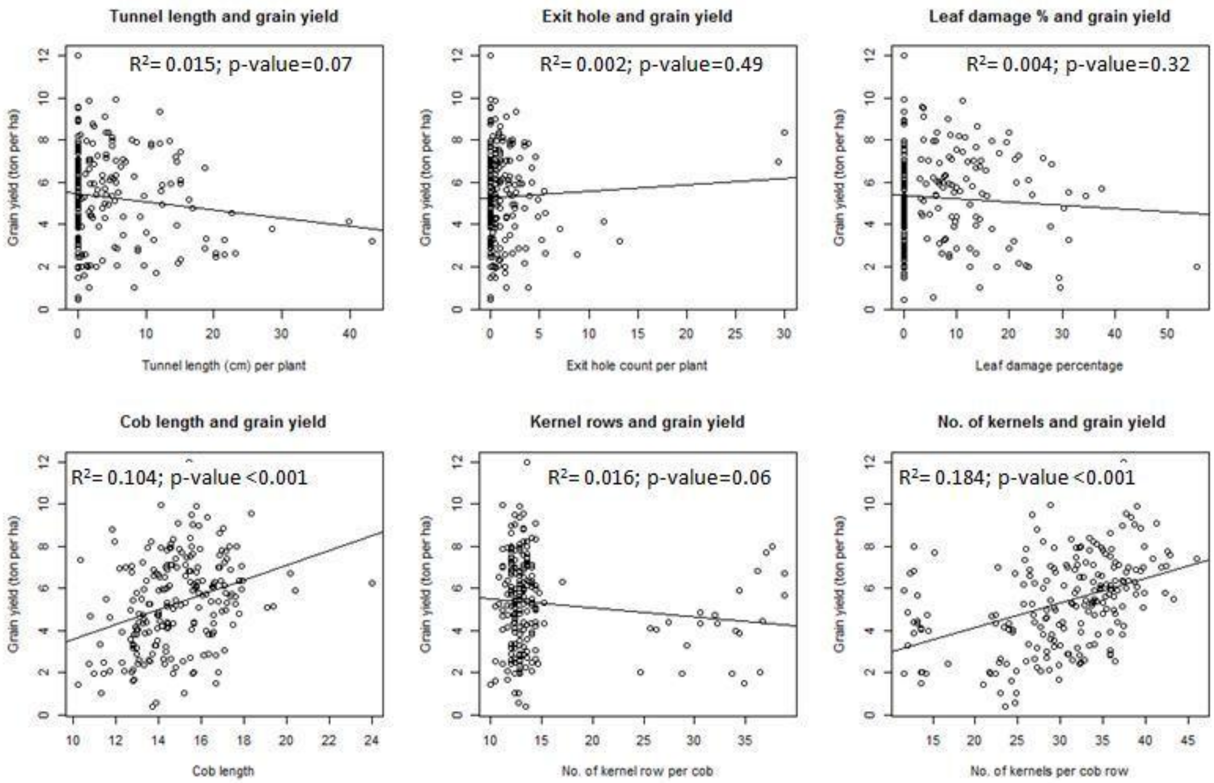


Figure 5 Relationship of stem borer damage parameters (tunnel length measurement, leaf damage percentage, and exit hole count per plant) with grain yield; and relationship of yield measurement traits (cob length, kernel rows per cob, and number of kernels per cob row) with grain yield

DISCUSSIONS

Two tested genotypes, promising hybrids: RML4/RML17 and RML32/RML17 have a common male parent, RML 17. Thus, the damage parameters, except tunnel length measurements, were recorded significantly different each other. In hybrid (F1) has a common male parent means share at least a 50% character of each so that a similar level of resistance mechanism against to maize stem borer damage. Similarly, other experiments have shown these two varieties showed moderate resistance against maize stem borer in terms of borer damage parameters (Anonymous, 20114). It would be possible that both varieties have capacity to recover the plant damage at early stage of the plant growth; thus showed no difference statistically on grain yield, although there was significant difference in plant damage parameters. Alternatively, in maize, one of the important herbivore-induced volatiles is terpene synthase TPS10, which is strongly expressed after the damage of lepidopteran pest, and it recruits natural enemies of the pest (Schnee *et al*., 2006). Furthermore, secondary metabolites in maize such as C-glycosyl flavones maysin and the phenylpropanoid product chlorogenic acid in silk are detrimental to growth and development to certain lepidopteraninsects, *Helicoverpa zea* and *Ostrinia nubilalis* respectively (McMullen, Frey & Degenhardt, 2009). Thus, it would be one of the possible reasons that the above mentioned secondary metabolites sufficiently produced by plants in our experimental field to recruit

natural enemies of the maize stem borer, as a result of that we were unable to observe the significant variation in plant damage percentage between the tested varieties.

In general, larvae of stem borer started to migrate from leaf to collar region, and thereafter initiate devouring in the stem. In this experiment, we observed similar level of preference by maize stem borer larvae in order to cause plant damage percentage on both of the tested genotypes at early stage of the plant growth; however, per plant stem tunneling measurement was higher (5.20 cm) in RML32/RML17 than per plant stem tunneling, 4.20 cm, of RML4/RML17 (Table 1). In this case, the female parent, RML32, of the tested genotype might contain at least some chemical cues that would enough to attract to maize stem borer adult. On the other hand, female parent, RML 4, of other tested hybrid may have contained certain specific metabolites that deter the growth and development of maize stem borer so that we observed lower stem tunneling data on it. Young leaves of maize contain maysin, which would deterrent chemical compounds to many herbivores, more than 300 µg per gram fresh weight of leaves (Maag, Bernal, Wolfender, Turlings, & Glauser, 2015). However, we need to conduct series of experiments to measure the available secondary metabolites in these inbred lines.

Borer damage parameter, exit holes count per plant, was not observed significantly different between the tested varieties (Table 1). Similarly, 4 and 3 number of exit holes per plant was on RML32/RML17 and RML4/RML17 respectively (Anonymous, 2013/14). In general, each of the exit holes on plant was made by stem borer larva, which was migrated from the stem somewhere to soil or base of the maize stem to spend its pupal stage. Thus, the reduced number of exit hole per stem means either the limited number of larvae were migrated from the stem where it fed; or even the larvae were inside the stem, the larvae were captive by the hardness of the stem. It provides sufficient ground for further investigation.

Different months of maize planting, from January to December, had significantly different on the measured borer damage parameters. It is obvious that almost each month had a wide range of minimum temperatures, maximum temperatures, humidity levels, and rainfall amount. Similarly, each organism has own level of requirements for their growth and development. Thus, an influence of these weather parameters to regulate growth and development of the larvae as well as adult of maize stem borers would not be beyond the

expectation. As adult population in the field fluctuates in response to ambient weather condition, the degree of damage by larvae may also be fluctuated. In this case, we clustered the all months of maize planting. Based on the observed data of borer damage parameters, we found a clear figure that August, December, October, July, September, April and November in one group; February, March and May is second large group; June in third group; and January in the fourth group (Figure 4 a, and 4 b). It is clearly observed from figure 1, 2, and 3 that the highest plant damage percentage was recorded in the planting month of June; the highest tunnel length measurement found on the maize plants that were planted on January; and the highest number of exit hole per plant found on the maize plants, which were planted in the month of February. It would be possible that during the planting month of January and February had lower number of plant damage because during this time period the average temperature was recorded less than 15 ^{0}C (Appendix 1) which would not be an ideal condition for the maize stem borer growth and development. In support of that Tamiru, Jembere, & Bruce (2012) suggested that *Chilo partellus* (Swinhoe), one of the important insect species of maize borers, takes longer duration to complete its life cycle at temperatures 22 ^{0}C as compared to higher 30^{0}C. Similarly, Neupane, Chapman, & Coppel (1986) reported that a 30^{0}C temperature range was an optimum for *C. partellus* development, and the subsequent threshold temperatures for eggs, larval, Pupal and entire life development were 13.2, 12.5, 12.7 and 13 ^{0}C respectively. Plants that were planted during the months of January and February had greater exit holes and longer tunnel lengths compared to other months, but lower plant damage percentage (Table 1). Here, temperature might have played a significant role for both maize growth and stem borer damage to maize plant. Additionally, longer tunnel length and greater counts of exit holes indicated increase level of borer activities. This could be possible that the growth and development of maize increased with increasing temperature and the duration of the maize growth in these two months of planting periods extended up to April and May (=fourth week of Jestha and Ashad), one of the peak period the maize stem borer dynamics (Gyawali, 1978). In agreement with that two open pollinated varieties, Across9942/Across9944 and S99TLYQ-B, had the highest tunnel length measurement as well as the highest number of exit holes count per plant in January planting than the measurements of any other months of maize planting (Achhami, Bhandari, Thakur, & B.K., 2014). Similarly, Thakur, Shrestha, Bhandari & Achhami (2013) also found similar pattern in tunnel length measurement and exit holes count in Chitwan condition but with different tested varieties than that is reported in our study. We observed that stem borer damage parameters did not show significant negative impact on grain yield. However, in a separate experiment, Odiyi, (2007) showed moderate to high correlations of leaf feeding damage, number of broken stems, and stems tunneling with grain yield. Similarly, 4-5 t ha^{-1} yield was reported by Neupane, Coppel, & Chapman (1984a) in Arun-2 maize variety despite the high stem borer damage (46.7% damage; 4.4 cm stem tunneling per plant). In conclusion,

January was the most damage prune planting month of varieties: RML32/RML17 and RML4/RML17 followed by June, whereas October and November were the lowest grain yield as compared to other month of plantings on these tested varieties in Chitwan condition. Thus, we recommend further studies related to interaction between maize varieties with secondary plant metabolites, potentially by using molecular tools to better understand maize stem borer biology and population dynamics in Chitwan condition.

REFERENCES

Achhami, B.B., Bhandari, G.S., Thakur, P. & BK., S.B., (2014).Seasonal variation in stem borer damage of maize at Chitwan, Nepal. *In*: Book of Extended Summaries, BM Prasanna, BS Vivek, AR Sadananda, D. Jeffers, PH Zaidi, C. Boeber, O. Erenstein, R. Babu, S. K Nair, B. Gerard, ML Jat, N. Palacios and K. Pixley (eds.) 12th Asian Maize Conference and Expert Consultation on "Maize for Food, Feed, Nutrition and Environmental Security" Bangkok, Thailand, October 30–November 1, 2014.CIMMYT, Mexico D.F. and APAARI, Bangkok, 133-140.

Anonymous, (2013/2014). Annual Report 2013/14, National Maize Research Program, Rampur Chitwan, Nepal.

Gyawali, B.K. (1978). Studies on the field biology of maize borer, Khumaltar Entomology Farm. Jyoti, J.L. & Shivakoti, G.P. (1992). A comprehensive overview of maize pests in Nepal. Review papers on maize research, National Maize Research Program, 27-30.

Maag, D.E., Bernal, J.S., Wolfender, JL., Turlings, T.C.J., & Glauser, G. (2015). Maize Domestication and Anti-Herbivore Defences: Leaf-Specific Dynamics during Early Ontogeny of Maize and Its Wild Ancestors. PLoS ONE 10(8): e0135722. doi:10.1371/journal.pone.0135722.

Malla, G. (2008). Climate change and its impact on Nepalese agriculture, The J. of Agric. and Env. vol. 9: 62-71.

McMullen, M., Frey, M., & Degenhardt, J. (2009). Genetics and Biochemistry of Insect Resistance in Maize, In: Handbook of Maize: Its Biology, J.L. Bennetzen and S.C. Hake (eds.), 271-289.

MoAD, 2013. Statistical information on Nepalese Agriculture (2013). Government of Nepal, Ministry of Agricultural Development, Agri-Business Promotion and Statistics Division, Agri statistics Section, Singha Durbar, Kathmandu, Nepal.

Nayava, J. L, & Gurung, D.B. (2010). Impact of climate change on production and productivity: A case study of maize research and development in Nepal, *The Journal of Agriculture and Environment*, 11, 59-69.

Neupane, F. P., Chapman, R. K., & Coppel, H. C. (1984). Temperature-developmental relationship of the maize borer, *Chilo partellus* (Swinhoe) Lepidoptera: Pyralidade) in Nepal, *Nepalese J. Agric*., 17, 23-35S.

Neupane, F. P., Coppel, H. C., & Chapman, R. K. (1984a).Susceptibility of maize cultivars and experimental materials to the maize borer, Chilo partellus (Swinhoe) in Nepal, *Nepalese J. Agric*., 15, 71-88.

Neupane, F. P., Chapman, R. K., & Coppel, H. C. (1986).Temperature-developmental relationship of the maize borer, Chilo partellus (Swinhoe) (Lepidoptera:Pyralidae) in Nepal. *Nepalese J.Agric*.,17, 23-35.

Odiyi, A. C. (2007). Relationship between stem borer resistance traits and grain yield reduction in Maize; correlations, path analysis and correlated response to selection. *Agricultural Journal*, 2(2), 337-342.

Paudel, B., Acharya, B. S., Ghimire, R., Dahal, K. R., & Bista, P. (2014). Adopting agriculture to climate change and variability in Chitwan: Long term-term trend and farmers' perceptions. *Agric. Res.* 3 (2), 165-174.

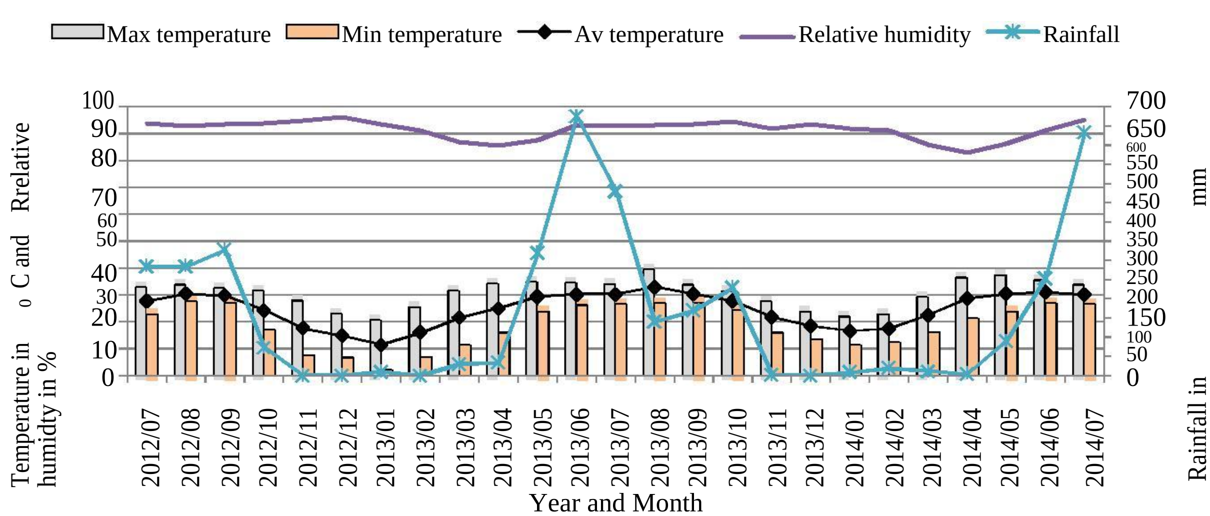
Schnee, C. , Köllner, T. G., Held, M., Turlings T. C. J., Gershenzon, J. & Degenhardt, J. (2006). The products of a single maize sesquiterpene synthase form a volatile defense signal that attracts natural enemies of maize herbivores . Proc. Natl. Acad. Sci. USA 103 , 1129 – 1134.

Sharma, P. N. & Gautam, P. (2010). Assessment of Yield Loss in Maize due to Attack by the Maize Borer, *Chilo partellus* (Swinhoe), Nepal Journal of Science and Technology, vol.11 (2010) 25-30.

Tamiru, E. G., Jembere, B., & Bruce, T. (2012). Effect of temperature and relative humidity on the development and fecundity of *Chilo partellus* (Swinhoe) (Lepidoptera: Crambidae). *Bulletin of Entomological Research*, 102(1), 9-15.

Thakur, P., Shrestha, J., Bhandari, G. S. & Achhami, B. B. (2013). Insect scenario and its succession in year round weekly interval seeded maize varieties at Rampur, Chitwan, Nepal,*International Journal of Modern Plant & Animal Sciences*, 1(2), 96-104.

Appendix 1: Weather parameters during the maize planting months from July 2012 to July 2014 at Rampur, Chitwan



Journal of Maize Research and Development (2015) 1(1):64-70

ISSN: 2467-9305 (Online)/ 2467-9291 (Print)
DOI: 10.5281/zenodo.34261

Use of optical sensor for in-season nitrogen management and grain yield prediction in maize

Bandhu Raj Baral[1]* and Parbati Adhikari[1]

ARTICLE INFO

Article history:
Received:
10th September, 2015 Reviewed:
7th October, 2015 Accepted:
2nd November, 2015

Keywords:
NDVI, GDD, response index, INSEY, grain N demand

ABSTRACT

Precision agriculture technologies have developed optical sensors which can determine plant’s normalized difference vegetation index (NDVI).To evaluate the relationship between maize grain yield and early season NDVI readings, an experiment was conducted at farm land of National Maize Research Program, Rampur, Chitwan during winter season of 2012. Eight different levels of N 0, 30, 60, 90, 120, 150, 180 and 210 kg N/ha were applied for hybrid maize RML 32 × RML 17 to study grain yield response and NDVI measurement. Periodic NDVI was measured at 10 days interval from 55 days after sowing (DAS) to 115 DAS by using Green seeker hand held crop sensor. Periodic NDVI measurement taken at a range of growing degree days (GDD) was critical for predicting grain yield potential. Poor exponential relationship existed between NDVI from early reading measured before 208 GDD (55 DAS) and grain yield. At the 261GDD (65DAS) a strong relationship (R^2 = 0.70) was achieved between NDVI and grain yield. Later sensor measurements after 571 GDD (95DAS) failed to distinguish variation in green biomass as a result of canopy closure. N level had significantly influenced on NDVI reading, measured grain yield, calculated in season estimated yield (INSEY), predicted yield with added N (YPN), response index (RI) and grain N demand. Measuring NDVI reading by GDD (261–571 GDD) allow a practical window of opportunity for side dress N applications. This study showed that yield potential in maize could be accurately predicted in season with NDVI measured with the Green Seeker crop sensor.

INTRODUCTION

Nitrogen is the most limiting nutrient for crop production and has the greatest effect on grain yield. Crop response to applied N is an important criterion for evaluating crop N requirement for maximum economic yield (Fageria and Baligar 2005). The management of N plays a key role in improving crop quality (Campbell *et al.*, 1995) and optimal N management will be influenced by crop type and crop rotation (Grant *et al.*, 2002). Previous research has shown that nitrogen (N) availability depends on seasonal changes in soil water content, temperature, soil structure, and organic matter distribution (Ranells and Wagger, 1992). Fageria and Baligar (2005) stated that improving nitrogen use efficiency is desirable to improve crop yields, reduce cost of production, and maintain environmental quality. Determination of the extent to which the crop will respond to additional N can help the farmers to apply only what

Corresponding author Info: [1]National Maize Research Program
*Rampur, Chitwan, Nepal *E-mail- bandhubaral@gmail.com*

is needed. There have been numerous studies that showed high correlations between certain vegetation indices developed from spectral observations and plant stand parameters such as plant height, percent ground cover by vegetation, and plant population (Raun *et al.*, 2005 and Stone *et al.*, 1996). NDVI (Normalized Difference Vegetation Index) is used widely for mapping plant growth. NDVI is defined as (NIR - Red) / (NIR + Red). The Red and NIR values represent the reflectance in the Red and NIR bands, respectively. Researchers at Oklahoma State University have developed an algorithm for maize nitrogen fertilization based on optical sensors. The N fertilizer rates depends on making an in-season estimate of the potential or predicted yield, determining the yield response to additional nitrogen fertilizer, and finally calculating N required obtaining that additional yield (Raun *et al.*, 2005).

MATERIALS AND METHODS

The experiment was conducted at the farm land of National Maize Research Program (NMRP), Rampur, Chitwan. NMRP is located in between 27°40’ N latitude and 84°19’ E longitude and an altitude of 228 m above mean sea level in the inner terai (Siwalik Dun Valley). The experiment was carried out during the September to February of 2013. The experiment was laid out in randomized complete block design (RCBD) with three replications. Eight different levels of N (0, 30, 60, 90, 120, 150, 180 and 210 kg N/ha) were applied for grain yield and NDVI measurement. Hybrid maize RML-32/RML-17 was planted in 12 sq. m plot with the row to row spacing 60 cm and 25 cm plant to plant spacing. Soil sampling was done before sowing and analyzed for total N, available P, available K, Soil Organic matter and pH. The soil type was *Ustic Psamments* (USDA classification) and was alluvial sandy loam in texture. The initial total N content was low (0.052%), available P was high (254 kg/ha), available K was medium (155 kg ha^{-1}), soil organic matter was low (1.57%) and very strongly acidic in pH (5.2). Plant Normalized Difference Vegetation Index (NDVI) was measured in each plot using a Green Seeker hand held Crop Sensor (NTech Industries, USA). Previous research showed that NDVI is an excellent measure of plant growth and N requirements (Raun *et al.*, 2005). In order to generate the algorithm, planting and emergence dates were recorded and used to compute the number of days from planting to sensing in each zone. For this method, we eliminated those days where Growing Degree Days (GDD) were equal or less than zero. The GDD values were calculated as: GDD = [(Tmin + Tmax)/2] – 10°C; where, Tmin and Tmax are the minimum and maximum temperatures, respectively. In Season Estimated Yield (INSEY), which is the yield with no added N, was calculated by dividing the plant NDVI by the number of days from planting to sensing (where GDD > 0). The Response Index (RI) was calculated by dividing the average NDVI readings from the high N plots by the average NDVI readings in the plots without N application. The predicted yield with added nitrogen (YPN) and grain N demand was calculated as described by Raun *et al.* (2002). Linear and nonlinear regression models were used to determine the relationships between grain yield and NDVI using Genstat.

RESULTS AND DISCUSSION

N level, NDVI and grain yield

Grain yield was significantly increased with applied N fertilizer (Table 2). Maximum grain yield was produced with 180 kg N/ha which indicated that increased in more than 180 kg N/ha had no yield benefit. The grain yield and NDVI measured in periodic interval showed a good correlation with grain yield and NDVI reading measured (Table 1 and Fig.1a). The NDVI reading was higher with increased N applied treatment (Fig.1b). The sensor reading taken at different date from planting to sensing date were calculated and described here as GDD. The NDVI measured at 261 GDD (65 DAS) showed a better fit among different GDD with r^2 =0.78 (Fig. 2). Measured higher NDVI reading to a limit had increased grain yield in RML-32 × RML-17 hybrid variety of maize at Chitwan condition. High correlations of early season NDVI readings with the plant biomass were also shown in the research conducted by Stone et al. (1996). Growth stage was a major factor in predicting yield potential. Regression analysis showed that weak exponential relationships occurred between NDVI and grain yield when sensor measurements were taken too early or too late (Table 1). This was probably a result of the failure in distinguishing the NDVI reading. However, a strong relationship between yield and NDVI was achieved at 261 GDD (Fig.1a) with an r^2 value of 0.70. Later sensor measurement (at 571 GDD and later) relationships with grain yield were similar to earlier (before 208 GDD) comparisons, where yield potential was not accurately determined (Table 2). Due to canopy closure influence on the sensor field of view, the later NDVI readings were unable to distinguish variation, similar to research findings for other remote sensing techniques measuring NDVI (Vin˜a *et al.* 2004).

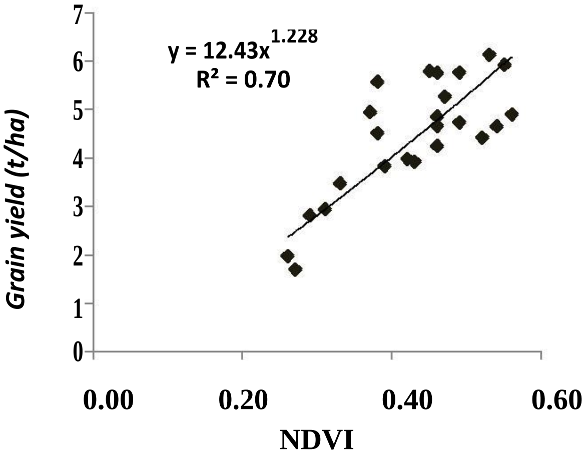


Fig. 1 (a)

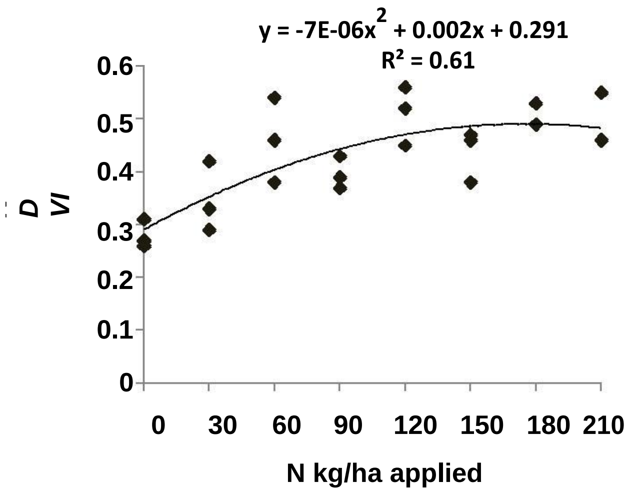


Fig. 1 (b)

Figure: 1(a). Relationship between NDVI and grain yield and 1(b) nitrogen doses applied and NDVI

Table 1: Correlation between NDVI measured at different days after sowing and other parameters

	GY	NDVI-115	NDVI-105	NDVI-95	NDVI-85	NDVI-75	NDVI-65	NDVI-55	DM-105	DM-75
GY										
NDVI-115	0.39									
NDVI-105	0.71	0.12								
NDVI-95	0.60	-0.10	0.65							
NDVI-85	0.78	0.07	0.52	0.43						
NDVI-75	0.74	-0.08	0.78	0.75	0.63					
NDVI-65	0.78	0.05	0.56	0.60	0.54	0.70				
NDVI-55	0.42	-0.09	0.41	0.60	0.27	0.62	0.56			
DM-105	0.73	0.40	0.51	0.42	0.14	0.60	0.57	0.31		
DM-75	0.10	-0.12	0.15	0.31	-0.15	0.07	0.17	0.17	-0.17	
SY	0.74	0.26	0.30	0.43	0.51	0.37	0.59	0.38	0.48	0.03

Predicted grain yield, response index and grain N demand

The predicted grain yields, INSEY, response index and grain N demand were significantly varied with N levels. The established relationship between the harvested grain yields and calculated INSEY showed a high correlation between yields and INSEY in this study (Fig. 2).The INSEY index estimates the plant biomass produced per day when growth was possible. Furthermore, Raun *et al.* (2002) showed that the plant NDVI readings and calculated INSEY can be used to predict grain yields. The INSEY was increased with increased N doses upto 120 kg N/ha after that not much varied (Table 3). The highest INSEY was recorded at 447 GDD which revealed that maximum greenness was obtained during that growth period. At early stage and later stage (before 261 GDD and after 571 GDD) the INSEYs were low and not much varied with N levels. This might be due to poor canopy cover and low chlorophyll content in leaves. The response index is the ratio of NDVI to without N and N rich plot. The RI indicates the fertilizer response to added N fertilizer and was explained by Johnson and Raun (2003). The RI was significantly affected with the N level and maximum RI was recorded at 120 kg N/ha applied and followed by 180 kg N/ha applied treatment. The maximum RI value of 1.84 indicated that 84% more grain yield can be obtained in comparison to without N fertilizer treatment with 120 kg N/ha with NDVI reading prediction (Table 2). The predicted grain yield was calculated with the RI. The Predicted grain yield was consistent only up to 120 kg N/ha after that inconsistent with applied N to the soil which indicates that the N applied was not used efficiently or poor N use efficiency which indicated that major applied N lost to the environment and we should improve N application in time or methods or rate. The grain production N demand was significantly affected with N level; however, it was based on predicted grain yield production. Our results showed that for the maximum grain yield of 4.75ton/ha production requires 59.8 kg N/ha available during in season. That amount was only for grain N demand but not for stover.

Table 2: Nitrogen level, measured grain yield, predicted grain yield, response index and grain N demand

S.N	N level (kg/ha)	Measured grain yield (t/ha)	Predicted grain yield (YPN)	Response index (RI)	Grain N demand (kg/ha)
1	0	2.21	2.61		0.00
2	30	3.43	3.23	1.25	17.32
3	60	4.47	4.29	1.65	47.00
4	90	4.24	3.70	1.42	30.51
5	120	5.04	4.75	1.84	59.80
6	150	5.24	4.07	1.58	40.66
7	180	5.55	4.70	1.80	58.35
8	210	5.45	4.57	1.77	54.65
F-test		**	*	*	**
LSD		1.00	0.85	0.37	23.9
CV%		12.8	12.2	12.1	35.5

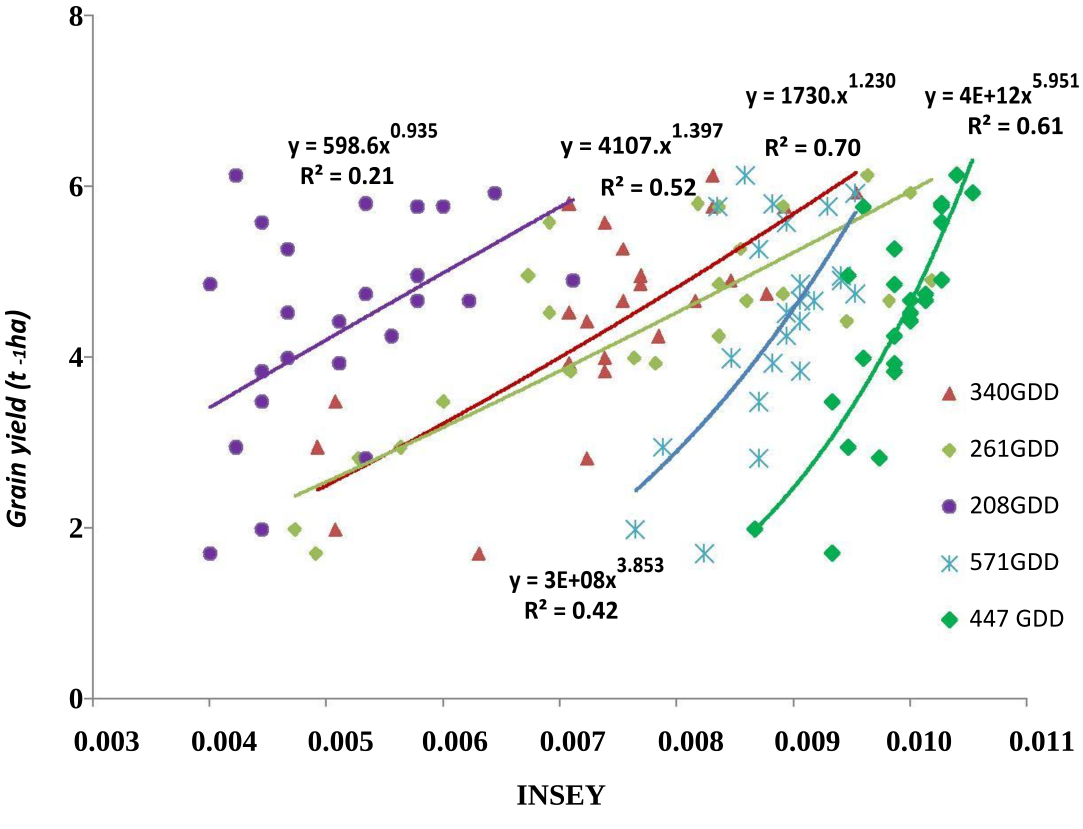


Figure: 2 Relationship between in season estimated yield (INSEY) calculated at different GDD and grain yield

Table 3: Effect of nitrogen level on in-season estimated yield (INSEY) measured at different GDD.

S.N.	N level (kg/ha)	INSEY						
		208 GDD	261 GDD	340 GDD	447 GDD	571 GDD	696 GDD	840 GDD
1	0	0.0042	0.005	0.0054	0.0092	0.0079	0.0076	0.0068
2	30	0.0048	0.0063	0.0066	0.0096	0.0086	0.0079	0.0066
3	60	0.0055	0.0083	0.0075	0.01	0.009	0.0081	0.0068
4	90	0.0051	0.0071	0.0074	0.0097	0.0091	0.0081	0.0068
5	120	0.0059	0.0092	0.0076	0.0102	0.0091	0.0081	0.0068
6	150	0.0044	0.0079	0.0075	0.01	0.0089	0.0082	0.0071
7	180	0.0052	0.0091	0.0087	0.0103	0.0091	0.0083	0.0068
8	210	0.006	0.0094	0.0087	0.0101	0.009	0.0081	0.0068
F-test		**	*	*	*	*	*	NS
LSD		0.0012	0.0016	0.001	0.0005	0.0005	0.0002	
CV%		12.4	12.3	8.4	2.9	5.3	1.7	3.3

CONCLUSION

Measuring NDVI reading by GDD (261–571 GDD) allow a practical window of opportunity for side dress N applications. This study showed that yield potential in maize could be predicted in season with NDVI measured with the Green Seeker crop sensor.

REFERENCES

Campbell, C.A., Myers, R.J.K., & Curtin. D. (1995). Managing nitrogen for sustainable crop production. *Fert. Res*. 42, 277–296.

Fageria, N.K., Baligar, V.C., & Bailey, B.A. (2005). Role of cover crops in improving soil and row crop productivity. *Comm. Soil Sci. Plant Anal.* 36, 2733-2757.

Grant, C.A., Peterson, G.A., & Campbell, C.A. (2002). Nutrient considerations for diversified cropping systems in the Northern Great Plains. *Agron. J.* 94, 186-198.

Johnson, G.V. & Raun, W.R. (2003). Nitrogen response index as a guide to fertilizer management. *Journal of Plant Nutrition*, 26, 249–262.

Ranells, N.N., & Wagger, M.G. (1992). Nitrogen release from crimson clover in relation to plant growth stage and composition. *Agron. J.* 84, 424-430.

Raun, W.R., Solie, J.B., Johnson,G.V. Stone, M. L., Mullen, R.W., Freeman, K.W., Thomason,W.E. & Lukina, E.V.(2002). Improving nitrogen use efficiency in cereal grain production with optical sensing and variable rate application. *Agron. J.*, 94(4), 815-820. http://dx.doi.org/10.2134/agronj2002.8150.

Raun, W.R., Solie,J.B., Stone, M.L., Martin, K.L., Freeman, K.W., Mullen, R.W., Zhang, H., Schepers, J.S.,& Johnson, G.V. (2005). Optical sensor based algorithm for crop nitrogen fertilization. *Commun. Soil Sci. Plant Anal*. 36, 2759-2781.

Stone, M.L., Solie, J.B., Raun, W.R., Whitney, R.W., Taylor, S.L.,& Ringer, J.D. (1996). Use of spectral radiance for correcting in-season fertilizer nitrogen deficiencies in winter wheat. Trans. *ASAE* 39(5), 1623–1631.

Vin˜a, A., Gitelson, A. A., Rundquist, D. C., Keydan, G., Leavitt, B., & Schepers, J. (2004). Monitoring maize (*Zea mays* L.) phenology with remote sensing, *Agric. J.,* 96, 1139–114

Journal of Maize Research and Development (2015) 1(1):71-85

ISSN: 2467-9305 (Online)/ 2467-9291 (Print)
DOI: 10.5281/zenodo.34286

A review on threat of gray leaf spot disease of maize in Asia

Narayan Bahadur Dhami [1*], S.K. Kim[2], Arjun Paudel[1], Jiban Shrestha[3] and Tirtha Raj Rijal[3]

ARTICLE INFO

Article history:
4th September, 2015 Revised:
10th October, 2015 Accepted:
8th November, 2015

Keywords:
Cercospora,
epidemiology,
inheritance, resistance

ABSTRACT

Biotic and biotic constraints are yield limiting factors in maize producing regions. Among these gray leaf spot is a yield limiting foliar disease of maize in high land regions of Asia. This review is done from related different national and international journals, thesis, books, research papers etc. The objectives of this review are to become familiar with genetics and inheritance, epidemiology, symptoms and disease management strategies etc. High relative humidity, temperature, minimum tillage and maize monoculture are important factors responsible for disease development. The sibling species of *Cercospora zeae-maydis* (Tehon and Daniels, 1925) Group I and Group II and *Cercospora sorghai var. maydis* (Chupp, 1954) are associated with this disease. Pathogens colonize in maize debris. Conidia are the source of inoculums for disease spread. Severe blighting of leaves reduces sugars, stalk lodging and causes premature death of plants resulting in yield losses of up to 100%. Disease management through cultural practices is provisional. The use of fungicides for emergencies is effective however; their prohibitive cost and detrimental effects on the environment are negative consequences. The inheritance of tolerance is quantitative with small additive effects. The introgression of resistant genes among the crosses of resistant germplasm enhances the resistance. The crosses of resistant and susceptible germplasm possess greater stability than the crosses of susceptible and resistant germplasm. The development of gray leaf spot tolerant populations through tolerance breeding principle is an economical and sustainable approach to manage the disease.

INTRODUCTION

Pests and disease are destroying about one fifth of all crop production around the world and at least 10% of the global food production is lost through plant disease alone (FAO, 2000) mainly in West Africa and South Asia. Maize (*Zea mays* L.) crop suffers from various biotic and abiotic constraints resulting in considerable yield loss. Among these, gray leaf spot is one of the most destructive and yield-limiting foliar disease in the world (Tehon and Daniels, 1925). The disease has been getting agricultural importance in tropical, subtropical and temperate maize growing areas worldwide in the last 30 years (Pingali and Pandey, 2002).

* *Corresponding author Info:*
Chief, Outreach divison, Khumaltar, lalitpur

1. *Outreach Division, Khumaltar, Lalitpur*
2. *National University of Korea*
3. *National Maize Research Program, Rampur, Chitwan, Nepal*

Historical perspective

Gray leaf spot (GLS) is caused by a fungus namely *Cercospora zeae-maydi*s (Tehon and Daniels, 1925). It was first observed in Illinois, USA in 1925 (Tehon and Daniels,1925). The pathogen first identified from a sample collected by Tehon and Daniels and confirmed by Chupp in 1953.There were very few records of this disease during the 1940s (Roane,1950). The disease was endemic in proportion and occasional outbreak during the period of the 1970s (Latterell and Rossi, 1983). The disease was recognized as destructive and yield limiting when increased incidence occurred in North Carolina (Leonard,1973). The severity and distribution of the pathogen has been increasing and the disease has become the most destructive throughout the maize growing regions of USA (Stromberg and Donahue, 1986; Ward *et al.,* 1999). This disease also occurred in South America (Chupp, 1953). GLS was first observed at Grey town in 1988-1989, Cedera in 1992 (Gevers *et al.*, 1994) and Kwazulu Natal in 1988 (Ward and Nowell,1997).

It was reported that GLS reached epidemic level in Natal South Africa during 1991-1992 (Gevers *et al.*,1994) and the first report was made in 1990 (Nutter and Jenco, 1992). It was reported that GLS was observed in Southern, Central and West Africa in the late 1980s and early 1990s (Ward and Nowell, 1997). Since then the pathogen became pandemic and spread rapidly in other provinces of South Africa as well as other countries in Sub Saharan Africa (Ward *et al.,* 1999).

Similarly it was recognized as a yield-limiting disease of maize in Asia, particularly in temperate regions of China (Ward *et al.,* 1999), India, South East Asia and the Philippines (Coates and White, 1994). Kim (2006 and 2008 personal communication) reported that GLS occurred in the northern part of China. Similarly GLS was first time observed in Nepal in 2006. It became epidemic in the Dhungkhark VDC of Kavre Planchowk district and Kaleswor, Gotikhel VDCs of Lalitpur district of Nepal (Dhami, 2006 unpublished; Manandhar, 2007). After few years; this disease was reported from hilly districts of eastern, western and mid western hills of Nepal. Similarly this disease was found epidemic in Bhutan (Katwal, 2008). The incidence and severity of this disease is increasing in others parts of Asia.

Importance of Maize

Maize is the important staple cereal and principle food of inhabitants of high land regions of Asia particularly in Nepal, Bhutan, China and India. It is mostly grown in upland rain fed conditions during summer season and low land in winter season. Relay and intercropping with finger millet, legumes, and potatoes and in rotation with wheat and barley are common practice in different parts of hilly regions. In case of Nepal, more than two thirds of maize production was directly consumed at farm level in high land areas of Nepal (Paudyal *et al.*, 2001). In the lowland areas less than 50% of the maize production is used for human food and a significant part goes to the market. Small and poor farmers use maize green cobs and early harvesting to combat hunger. It is a source of green fodder and dry stover to feed the cattle. The dry stalks are a source of domestic energy (fuel wood) as well as a means to prevent soil erosion. In accessible areas, it is becoming an industrial as well as a commercial crop. However in high land regions it is used as human food rather than other purpose. Since past few years, GLS disease became the major problem to reduce grain yield in these regions. It was estimated that a 50-100% yield loss was observed in Bhutan (Katwal, 2008)

and >80% was estimated in Nepal (NARC, CIMMYT and DOA, 2007 unpublished).The maize growing environments, production systems and socioeconomic characteristics of Nepal, Bhutan and other high land regions of Asia are relatively similar. In a view of these circumstances maize is the most important crop interms of food feed, fodder etc. It is urgent need to increase maize production for sustainable livelihood in these regions and is ranked as a high research priority problem of maize production by national and international maize research organizations.

Epidemiology and factors associated with disease development

The GLS epidemic primarily depends upon three factors that interact with time and space. (1) The initial amount of inoculums (2) rate of reproduction of the pathogen within season and (3) proportion of healthy tissues remaining to be infected. High relative humidity, temperature (Latteral and Rossi, 1983; Stromberg, 2000) wide adoption of minimum and conservation tillage and maize monoculture (Payne and Waldron, 1983; Ward *et al.,* 1999) are equally important for GLS pathogen development. Relative humidity of 95% is optimal for germ tube elongation and formation of appressoria (Thorson and Martinson, 1993). Paul et al.(2005) observed that, sporulation is high at 100% relative humidity and 25^{O}C-30^{O}C temperature but the number of lesions and lesion expansion were not significantly different with >25^{O}C temperature. GLS was slow to develop when the mean daily temperature dropped below 20^{O}C (Ward, 1996; Nowell, 1997). Generally disease severity increases during mid to late summer due to favorable conditions for lesions expansion (Paul *et al.,* 2005). Ward and Nowell (1998) reported that incidence and severity of disease is usually associated with the amount and distribution pattern of rainfall. Early rains favor the development of primary lesions. Disease severity occurred more on warm humid, prolonged overcast, misty and cloudy days (Rupe *et al.,* 1982; Stromberg, 2000). In temperate regions maize monoculture, growing susceptible, local cultivars (de Nazareno *et al.,* 1993; Manadhar, 2007), plowing by locally fabricated ploughs and other biophysical factors favor pathogen development. Residues in neighboring fields may serve as a potential source of inoculums (de Nazareno *et al.,* 1993). The practice of stacking maize stalks in the field, feeding maize stovers to animals, use as animal bedding and use of und decomposed compost may spread the pathogen inoculums.

Similarly, stalk mulching, partially harvested maize stovers left standing in relay and intercropping fields may stabilize the pathogen. Blowing wind in the dry season may facilitate the dissemination of the pathogen up to 80-160 km each year (Ward *et al.,* 1999). The deficiency of mineral nutrients may have a potential role in GLS epidemics (Smith, 1989; Ward, 1996).

Disease cycle

Cercospora zeae-maydis (Tehon and Daniels,1925) is a polycyclic facultative pathogen (Chupp, 1953; Stromberg and Donahue, 1986). The fungi over winters as mycelium and stromata in infected maize residues left over the soil surface (Payne and Waldron, 1983). After harvesting maize fungus colonize on residues and produces conidia and disease cycle starts in spring (Payne and Waldron, 1983; Stromberg, 2000). The conidia disseminated to new corn plants by wind and splashing rain drops (Lipps, 1998). These new born conidia provide primary inoculums to infect newly planted maize fields (Latterell and Rossi, 1983; Payne and Waldron, 1983). The spores (conidia) infect the lower leaves through the stomata

and colonize leaf tissues. Conidia are produced from two to four weeks after initial leaf infection. Sporulation may be delayed in genotypes with moderate levels of resistance (Beckman and Payne, 1983). The fungus can remain dormant during the dry part of summer and then become active when conditions are favorable (Stromberg, 2000). The latent period of the pathogen is longer and can take as long as 14-28 days after infection for lesions to sporulate (Beckman and Payne, 1982; Stromberg, 1986). In about two weeks, these lesions will generate new spores and produce appresoria over stomata before penetrating the host tissue. Secondary cycles of disease are initiated by conidia produced within the lesions. Prior to grain filling very few infection cycles occur because of the long latent period (Beckman and Payne, 1982). Under favorable climatic conditions, disease progress can be rapid during the grain filling stage of crops.

Disease symptoms

The expression of symptoms depends on the genetic background of the genotype (Kim *et al.*, 1989). Resistant genotypes express the fleck type of lesions due to resistance gene (Latterell and Rossi, 1983). Moderately resistant genotypes exhibit chlorotic lesions (Roane *et al.*,1974) and the susceptible genotypes display necrotic spots (Latterell and Rossi, 1983). Early symptoms of GLS can be confused with symptoms of other foliar diseases particularly with southern leaf blight and northern leaf blight (Stomberg, 1986). GLS has two distinct features. Lesions occure as gray to tan in color and are distinctly rectangular in shape (5-70 mm long by 2-4 mm wide), and tan spot running parallel to leaf veins (Laterell and Rossi, 1983; Ayers *et al.*,1984; Stromberg, 1986).

The fungus generally produces spores on the lower side of leaves and the spore bearing structures may appear as small black specks. Early symptoms of infection include pinpoint lesions surrounded by yellow haloes. The early lesions are transparent when the leaf is held against the light while mature lesions are completely opaque (Latterell and Rossi¸1983; Smith and White, 1987). Leaf veins restrict pathogen growth and lesion width, but lesion width may vary with the distance between veins and proximity to other lesions. The lesions merge and kill entire leaves during favorable weather condition. The severe blighting of leaves and leaf sheaths are followed by stalk rotting and severe lodging (Stromberg, 1986), and premature death of leaves (Latterall and Rossi, 1983; Stromberg and Donahue, 1986; Stromberg, 2000). If the incidence and severity of disease is high during anthesis, the affected plants are fully dried but the ears have green husks, fresh silks, barren or partially filled ears and shrunken kernels (Manadhar, 2007).

Effects of GLS on crop

GLS reduces the grain yield and quality of silage maize. The yield loss has been estimated and quantified by researchers in Iowa, Virginia, Africa, China, Nepal and Bhutan. Researchers reported that, grain yield loss was found high when disease severity occurs during vegetative and tasseling/silking to grin filling stage and low grain yield loss was found after grain filling stage. Other several factors may contribute to this response, including yield potential of the cultivars, growth stage of crops and the ability of leaf blighting to predispose the variety to stalk rots. Documented yield losses of maize attributed to GLS vary from 11 to 69% (Ward *et al.,* 1999). Most of the researchers estimated that losses as high as 100% occurred when the pathogen attacked before the flowering stage (Stromberg and Donahue, 1986, and Lipps *et al.,* 1996). The blighting of leaves and stalk rotting caused the premature

death of leaves which reduced the amount of sugar and resulted in significant yield loss. Early blighting of the leaves above the ear leaf has led to yield losses of more than 50%. Blighting and premature death of the upper eight or nine leaves which contribute 75-90% of the sugar for grain filling resulted in a high level of yield reduction (Allison *et al.,* 1996).

Rupe *et al.* (1982) found that symptoms appearing before anthesis irrespective of planting date caused greater yield loss. Nutter and Jenco (1992) observed that disease severity at late dough stage resulted in a variation in yield of up to 90%. Late planted maize has greater GLS severity and a higher reduction in yield than earlier planted maize (Lipps, 1995; Manandhar, 2007).

Species of Cercospora

The genus *Cercospora* is a member of deuteromycetes and belongs to one of the largest groups of plant pathogenic fungi (Goodwin *et al.,* 2001). Initially *Cercospora zeae-maydis* was considered to be the sole causal agent of gray leaf spot. Recently it was accepted that three genetically distinct species of *Cercospora* are associated with this disease. Among the two sibling species of *Cercospora zeae-maydis;* Group I *Cercospora zeae-maydis* and Group II *Cercospora zeina* (*Crous et al.,* 2006) and *Cercospora sorghai var. maydis* were associated with this pathogen. The two sibling species (Group I and Group II) are genetically distinct but morphologically similar (Carson *et al.,* 1997; Wang *et al.,* 1998) and uniform internally with a genetic similarity of approximately 93 to 94% (Wang *et al.*, 1998). The genus *Cercospora sorghai var. maydis* is saprophytic and found in maize tissues (Carson and Goodman, 2006). It is associated with GLS lesions however, its pathogenicity is not confirmed (Chupp, 1953).The internal transcribed sequence of the *C. zeina* isolate was more similar to that of an isolate of *C. sorghi* var. maydis than to that of *C. zeae-maydis*. Although Group I can be distinguished from Group II by its faster growth rate of conidia (8-12mm per week) when compared to that of *C. zenia* (4-5 mm per week) in artificial media. Group I has the ability to produce cercosporin, longer conidiophores and broadly fusiform conidia, whitish to grayish mycelia, irregular edge and visible quantities of reddish toxin (cercosporin) where as Group II contains mycelia whitish to grayish in color with olive green mycelia, irregular edges on top and no visible reddish toxin. Although two isolates have some differences in morphology and the production of cercosporin. They produce exactly the similar symptoms in maize. Group I is prevalent and predominates over *C. zeina* throughout the maize growing areas of the eastern and midwest regions in the USA, Latin America, China, India, Nepal and Bhutan. Group II species are confined to Africa and the Eastern US. Meisel *et al.* (2009) found that, Group II (*Cercospora zenia*) is the causal agent of GLS in Southern Africa. Similarly Crous *et al.* (2006) reported that, the Group II pathotype is prevalent and predominant in East Africa but the origin of the pathogen is unknown. It is generally accepted that *C. zeina* originated in Africa but spread from sorghum (indigenous host) to maize. *C. zeina* has higher genetic variability in Africa compared to the USA (Dunkle and Levy, 2000). They also argued that the GLS pathogen was introduced to the USA from Africa.

Inheritance of gray leaf spot

Different gene actions are involved for early season and late season resistance to gray leaf spot (Bubeck *et al.,* 1993, Coates and White, 1998). The expression of resistance is affected by the genetic background of a susceptible parent (Kim *et al.,* 1989) and microclimatic

conditions (Payne and Waldron, 1983). Several genetic studies (Verma, 2001; Menkir and Ayodele, 2005; Donahue *et al.,* 1991) reported that the resistance to GLS was quantitatively inherited with a preponderance of additive gene action and possible minor dominant and epistatic gene effects which, contributed to the resistance. Manh (1977) reported that, additive genetic effects accounted for 82 to 96% of the total variation in GLS resistance among generations, although dominance and epitasis provided some contribution. In diallel cross analysis of GLS resistance Gevers and Lake (1994) found that additive and non additive genetic effects were important in GLS resistance. South African researchers found high frequency of quantitative resistance to GLS present within commercial hybrids (Nowell, 1977). In addition to quantitative resistance, a qualitative resistance to GLS was observed in maize genotype in South Africa (Gevers *et al.,* 1994) and it was observed that non-additive genetic effect plays a significant role in resistance mechanism. He reported that crosses between resistant and the most susceptible inbreeds resulted in resistant hybrids due to the predominantly additive nature of gene actions and major dominant effects of some genes. Quantitative resistance to GLS has been found to impact on lesion size, latent period and sporulations (Ayers *et al.,* 1994). Host resistance is regulated by a small number of quantitative loci with five or more genes involved which are inherited additively (Ayers *et al.,* 1985; Thompson *et al.,*1987; Bubeck *et al.,*1993; Saghai-Maroof *et al.,* 1996). Clements et al. (2000) found that five quantitative trait loci (QTLs) were significantly associated with GLS resistance. Four of them were associated with ear height relative to plant height. Li-yu *et al.* (2007) reported that a total of 57 QTLs for GLS resistance were found and located in each chromosome. They were primarily found in chromosome 1, 2, 4, 5 and 8. Ward and Nowell (1988) reported that QTL 1 and 2 had additive effects for GLS resistance, 4 had a dominant/recessive component and 8 had a recessive effect. Chromosome 8 was included in both parental lines for higher GLS resistance in hybrids. Saghai-Maroof *et al.* (1996) observed that the QTLs located in three chromosomes (1, 4 and 8) had large effects on GLS resistance and were consistent. QTLs with smaller effects were found in chromosome 2 and 5. Chromosome-1 QTL had the largest effect. However, the findings regarding the chromosome 5 might have been false. Chromosome 4 belonged to the susceptible parent and all 3 chromosome (1,4 and 8) were from the resistant parent. The use of inbred strains that were highly resistant to GLS produced highly resistant crosses (Ivanovic *et al.,*1982; Gevers and Lake, 1994) and the intermediate GLS resistant inbreed strains produced highly susceptible hybrids (Huff et al., 1988).Whereas Coates and White (1994) reported that several inbreeds line identified as resistant to GLS did not produce resistant hybrids in crosses with a susceptible tester line. The introgression of resistance genes through the crosses of resistant with resistant germplasm enhanced the high level of resistance which was useful to develop resistant inbred strains (Menkir and Ayodele, 2005). They observed that the GLS score was significantly higher among the crosses of susceptible with resistant germplasm as compared to the F_1s of resistant with susceptible germplasm. They also reported that the F1s of resistant with susceptible germplasm were more durable. However the yield difference was not significant. The cytoplasm genes contributed significantly to the variation in GLS scores among hybrids, hence from the crosses between susceptible and resistant lines, the resistant line (VA14) could be used as a female parent to enhance the level of resistance (Menkir and Ayodele, 2005).

Disease Management

Cultural practices reduce the pathogen inoculums but some losses from disease are inevitable in areas where the disease is endemic and of epidemic proportion. However these practices are recommended as immediate actions to minimize yield loss.

Crop rotation and cropping pattern

Maize is the only host crop this fungus is known to attack. Rotation of the non host crop for two years can reduce the disease inoculums effectively where the management of conservation tillage and field sanitation is equally important (Lipps, 1998; Wolf, 2002). However there is no alternative crop to replace the maize for crop rotations in hills. The possible crops for rotation are soybean and potato. Mixed cropping of soybean with maize, relay and intercropping of finger millet are widely used practices. Mixed or inter cropping hinders air circulation inside the crop field which helps to increase relative humidity and favors disease development. Cultivation of wheat in maize cultivated field is not recommended, because *Gibrella zeae*, is one of the most common causes of corn stalk rot. Wolf (2002) pointed out that the incidence and severity of head scab in wheat may be due to ear rot of maize.

Tillage practices

There is a positive correlation between tillage practices and disease epidemics. Conventional tillage incorporates the surface residues in to the soil. The burial of infested debris facilitates rotting and deprives the fungus of a food base. However conventional tillage may be effective only in regions where external inoculums are minimal (Payne *et al.*, 1987). Zero and minimum tillage favor the disease development because of old maize residues left over the soil surface in the field.

Residues and Weed management

The infected residue of a previous crop left over the soil surface is the principal source of inoculums. There was a strong positive correlation between the amount of infected maize residue and disease inoculums (Asea *et al.*, 2002; de Nazareno *et al.*, 1993a). They reported that disease intensity was higher in a high residue treated plot than a non treated plot. The collection of stovers which are stacked in the field and near the home stead, is a common practice. This practice may help to keep the field clean and reduce disease inoculums. However it is not always practiced for the following reasons, maize stalks are mulched and dried stovers are used for animal bedding. The use of un decomposed compost also harbors and disseminates the disease inoculums. Weed management practices increase air flow within the crop canopy, reduce relative humidity and help limit the time period favorable for pathogen infection (Wolf, 2002).

Maintain the plant density

High plant density creates high relative humidity and a microclimate which favors disease development (Beckman and Payne,1983; Payne and Waldron,1983; Ayers *et al.*, 1985) where

as de Nazareno *et al.*(1993a and 1993b) argued that high plant density has less disease incidence because of less air flow to disseminate secondary inoculums.

Adjustment in time of planting

Most of the researchers reported that, late planted maize was more affected than early planted maize because disease development was slow due to unfavorable environmental condition early in the season (Payne and Waldron, 1983). They also suggested planting early maturing cultivars earlier in the season to minimize the yield loss. The late planted maize tended to develop more severe GLS, because the plants experienced initial infection at earlier stages and there was a greater opportunity for multiple cycles of infection before the plants

reached their physiological maturity (Stromberg and Donahue, 1986; Bhatia *et al.,* 2002). Early maturing cultivars escape from disease because plants face first cycle of infection at physiological maturity stage. Assured irrigation is crucial for timely planting but in these regions planting maize primarily depends upon monsoon rain.

Balanced use of fertilizers

Application of chemical fertilizers significantly affected GLS progress (Okorai *et al.,* 2004). They reported that GLS epidemic was significantly higher in non fertilized plots than fertilized plots. They also observed that a single application of nitrogen increased the predisposition of plants to GLS but a combined application of nitrogen and phosphorus at a recommended level significantly reduced the predisposition effect of a high nitrogen level. The unbalanced use of nutrients caused host nutrient deficiency and losses of resistance status predisposed the plants to GLS (Smith, 1989; ward, 1996). Maize growers in hills and remote areas do not have access to fertilizers because of high cost and less developed infrastructures. The use of farm yard manure and compost is a common and widely adopted practice in these areas. These organic manures are useful for improving the soil‟s physical properties but they do not supply the required amount of nutrients to the maize plants.

Use of fungicides

Fungicides are only recommended for an emergency on susceptible hybrids and previously infected crop fields. Tilt (active ingredient propiconazole) and Quadris (azoxystrobin) are effective to manage GLS. The use of fungicides to control GLS in maize seed production is cost effective but it is not directly applicable to grain production (Shaner *et al.,* 1999). Smith (1988) found that the Benzimidazole group of fungicides has commonly used in many crops and in some cases pathogens have developed resistance rapidly. The use of fungicide is beyond the access of resource constrained farmers and moreover increases the production cost, hazardous to human health and has a negative impacts to environment.

Tolerance crop breeding principle

The development of a host that is resistant to biotic and abiotic factors is cost effective and environmentally sound. The two terminologies are frequently used in resistant ie. horizontal resistance and vertical resistance (Vanderplank, 1978). Horizontal resistance (tolerance) remains effective while being extensively used in agriculture for long periods in an environment conducive to disease. This tolerance crop breeding principle is the use of quantitatively inherited genes to breed new crops to combat biotic stress (Kim *et al.,* 2009). This principle depends on the number of genes and gene action involved (Kim, 2000). This principle does not aim at absolute (100%) controls but attempts to attain partial control (95%). The concept of tolerance is similar to "partial resistance", "general resistance", "horizontal resistance", "durable resistance", and "mature plant resistance" (Kim 1994a, 1996b). It is partial and race- non specific in phenotype, oligogenic or polygenic in inheritance and is conditioned by additive or partially dominant genes (Gevers and Lake, 1994) and allows the survival and development of the pathogen. The tolerant host is attacked by the pathogen in the same manner as the susceptible genotypes, but there is little or no loss in biomass production or yield (Kim, 1996b; Singh, 2005). It provides the space for host flexibility and host adjustment in a changing environment. This is useful to producers particularly for those who are subsistence farmers of underdeveloped countries (Kim, 1996b; Ward *et al.,* 1999).

Resistance is synonymous with complete resistance, true resistance and vertical resistance with hypersensitive response. With this principle host plants provide the negligible space for pathogen development. In the case of resistance, the reproduction rate of pathogen „r‟ is 0 or close to 0, but in the case of tolerance „r‟ is never 0. Because „r‟ is smaller than 1 (100%) but greater than 0, this principle aims at absolute (100%) control, complete or a high resistance until resistance genes work, but can be lost through an associated and matching change in the virulence genes in the pathogen (Vanderplank, 1978). The complete control (100%) by a single gene always creates selection pressure that may invite about the mutation of pest (Kim, 2000).

Future Strategies

Increase crop diversity and broadening the base of germplasm

Maize is not a native crop in Asia thus the genetic base is narrow particularly in temperate regions. The maintenance of adequate genetic diversity in crop plants is a prerequisite for plant breeding (Goodman, 1999). The crop plants gradually become vulnerable to disease and pests because of an elimination of host diversity within a very homogeneous host population (Strange and Scott, 2005). The genetic vulnerability in locally used breeding materials and commercial hybrids would enhance the disease severity (Givers and Lake, 1994). The genetic mixtures possess greater stability of performance and their inherited resistance to disease is more effective and more durable (Wolf, 1993). Exotic germplasm is a potential source of new alleles for introgression into adapted germplasm to increase the variability (Goodman, 1985). The use of a resistance source for conversion and incorporation would be better from the sources in the same heterotic group (Kim, 2000). These are a useful source of alleles for resistant to disease, insect pests and for broadening the genetic base of temperate germplasm (Goodman 1999). Eberhart *et al.* (1995) proposed the use of elite exotic germplasm with high yield potential and resistance to disease and insects as a good strategy for integrating genetic

diversity into maize breeding populations. It is crucial to cross the CIMMYT and IITA maize germplasm with locally adapted and introduced germplasm.

Selection and development of tolerant cultivars

The development of locally adapted tolerant cultivars enhances the durability of resistance (Nowell, 1997). The breeder should practice selecting the tolerant genotypes from adapted germplasm based on yield potential and stand ability under disease pressure. Plants with mild symptoms of the disease and good yield at maturity will have the highest tolerance (Kim, 2000). The incorporation of new genotypes, either local or exotic, in the evaluation of a breeding program increases the availability of genes for resistance that were not previously available. For example; in Nepal, NARC and CIMMYT scientists found Deuti, Manakamana-3 and Ganesh-1 to be relatively tolerant with GLS (NARC, CIMMYT and DOA, 2007 unpublished).

Similarly Ashom I and Ashom II varieties were found tolerant in Bhutan (Katwal, 2008). These improved open pollinated varieties should be crossed with GLS resistant materials either locally developed or introduced. As the inheritance of GLS resistance is mainly quantitative in nature, the frequency of resistant alleles in a population can be increased by population improvement techniques. Recurrent selection can be an effective method to incorporate and accumulate the resistant genes in elite breeding materials if several genes with additive gene action are involved. This method of selection increases the frequency of favorable alleles for the trait under selection (Goodman, 1999) and maintains the genetic variability of the population through the recombination of genes between cycles of selection and permits continued selection.

The International Maize and Wheat Improvement Centre (CIMMYT), Institute of International Tropical Agriculture (IITA) and International Corn Foundation (ICF) have been given the high priority problem of managing GLS disease in these regions. CIMMYT, IITA and ICF are providing financial, technical and germplasm support. CIMMYT has been conducting collaborative GLS disease research activities in Nepal and Bhutan (Manandhar and Katwal personal communication). The gray leaf spot screening nursery has been completed in disease hot spot area in Nepal. Based on their GLS disease response and overall agronomic performances, resistant population ZM627, ZM401, ZM525, and 07SADVI have been identified. Similarly some tolerant inbreeds and CIMMYT hybrids having good yield potential were identified. OPvs, synthetics, hybrids and inbreeds will continuously testing in artificial inoculated as well as natural GLS hot spot area to evaluate their tolerance level.

CONCLUSION

GLS is still causing enormous yield losses in tropical, subtropical and temperate regions. It has threatened the sustainable food production and livelihood of the communities in Asia. This condition will become worse in the developing countries where maize is the staple food. Thus it is becoming the major concern of plant breeders and pathologists. The effort and research focused on this disease has been mainly concentrated in the USA and Africa. There is not a sufficient source of information about this disease in Asia. Very limited work has been done in the molecular aspect in China. In collaboration with CIMMYT/Mexico and ICF/Korea, scientists of NARC/Nepal and Bhutan have initiated preliminary research. Thus the concerned national and international organizations primarily CIMMYT and IITA should concentrate their efforts in under developed countries otherwise this disease may become the

primary cause of grain yield loss in these regions. Chemical recommendation for disease management is only the acceptable for emergency situations. Chemicals should not be applied in breeding nurseries. The breeding of crops through the tolerance principle is effective for resource constrained farmers. This is the durable and economical means for disease management. This principle is equally important for an eco-friendly environment.

ACKNOWLEDGMENTS

The authors would like to express their sincere thanks to Agriculture Botany Division, Agricultural Research Council Singh Durbar, International maize and Wheat Improvement Centre, Mexico, International Corn Foundation and International Agricultural Research Institute of Kyungpook National University of Korea for their kind support and cooperation. The authors also would like to express their gratitude to S.P. Khatiwada chief of Agriculture Botany Division, NARC.

REFERENCES

Allison, J.C.S., & Watson, D.J. (1996). The production and distribution of dry matter in maize after flowering. *Ann. Bot.*, 30, 365-381.

Asea, G., Bigirwa, G., Adipala, E., Owera, S.A.P., Pratt, R.C., & Lipps, P.E. (2002). Effect of *Cercospora zeae-maydis* infested maize residue on progress and spread of gray leaf spot of maize in central Uganda. *Ann. Appl. Biol.*, 140, 177-185.

Ayers, J.E, Johnson, M.W.,& Hill, R.R. (1985). Identifying resistance to gray leaf spot. Pages 157-175 In: Proc.39th Maize Sorghum Res. Conf. American. seed trade assoc., Washington, DC.

Ayers, J.E., Johnson, M.W., & Hill, R.R. (1984). Identifying resistance to gray leaf spot. Pages 157-175. In:Proc. Maize Sorghum Res. Conf., 39th. Am. Seed Trade Assoc, Washington D.C

Beckman, P.M., & Payne, G.A. (1983). Cultural techniques and conditions influencing growth and sporulation of *Cercospora zeae-maydis* and lesion development in corn. *Phytopathology*, 73, 286-29.

Beckman, P.M., & Payne, G.A. (1982). External growth, penetration and development of *Cercospora zeae-maydis* in corn leaves. *Phytopathology* , 72, 810-815.

Bhatia, A., & Munkvold, G.P. (2002). Relationship of environment and cultural factors with severity of gray leaf spot in maize. *Plant disease*, 86 (10),1127-1133.

Bubeck , D.M., Goodman, M.M., Beavis, W.D., & Grant, D. (1993). Quantitative trait loci controlling resistance to gray leaf spot in maize. *Crop Sci*., 33, 838-847.

Carson, M.L., & Goodman, M.M. (2006). Pathogenicity, aggressiveness, and virulence of three species of Cercospora associated with gray leaf spot of maize. *Maydica*, 51, 89-92.

Carson, M.L., Goodman, M.M., Williamson, S.M., Haralambous, V., & Nyanapah, J.O. (1997). Pathogen variability as a potential cause of G x E interaction in maize gray leaf spot trials (Abstr.). *Phytopathology*, 87, S15.

Chupp, C. (1954). Amanagement of the fungus genus *Cercospora lthaca*, New York.

Chupp, C. (1953). A monograph of the fungus genus *Cercospora*. Cornell University press, Ithaca, NY.667 pp.

Clements, M.J., Dudley, J.W., & White, D.G. (2000). QTL associated with resistance to gray leaf spot of corn. *Phytopathology*, 90, 1018-1025.

Coates, S.T., & White, D.G. (1998). Inheritance of resistance to gray leaf spot in crosses involving selected resistant inbred lines of corn. *Phytopathology*, 88, 972-982.

Coates, S.T., & White, D.G. (1994). Sources of resistance to gray leaf spot of corn. *Plant disease*, 78, 1153-1155.

Crous, P.W., Johannes, Z.G., Marizeth, G., Pat, C., Uwe, B., & Thomas, C.H. (2006). Species of Cercospora associated with grey leaf spot of maize. *Stud Mycol.*, 55(1), 189-197.

De Nazareno, N.R.X., Lipps, P.E., & Madden, L.V. (1993a). Effect of levels of corn residue on the epidemiology of gray leaf spot of corn in Ohio. *Plant Disease*,77, 67-70.

Donahue, P.J., Stromberg, E.L., & Myers, S.L. (1991). Inheritance of reaction to gray leaf spot in a diallele crosses of 14 maize inbreds. *Crop Science,* 31, 926-931.

Dunkle, L.D., & Levy, M. (2000). Genetic relatedness of African and United States Populations of *Cercospora zeae maydis*. *Phytopathology*, 90, 486-490.

Eberhart, S.A., Sevilla, W.R., & Aba, S.T. (1995). Principles for tropical maize breeding. *Maydica*, 40, 339-355.

FAO. (2000). The state of food insecurity in the world (SOFI). Rome, Italy: FAO, UN. www.fao.org/FOCUS/E/SOFI00/sofi001-e.htm

Gevers, H.O., & Lake, J.K. (1994). Gray leaf spot –a major gene for resistance to gray leaf spot in maize. *S. Afr. J. Sci.*, 90,377-380.

Gevers, H.O., Lake, J.K., & Hohls, T. (1994). Diallele crosses analysis of resistance to gray leaf spot in maize. *Plant disease* , 78,379-383.

Goodman, M.M. (1985). Exotic maize germplasm: status, prospects and remedies. *Iowa State J. Res.*, 59,497-5274

Goodman, M.M. (1999). Broadening the genetic diversity in maize breeding by use of exotic germplasm. In: Coors J. G., Panday S. (eds) Genetics and exploitation of heterosis in crops. ASACSSA, Madison, WI, pp139-148

Huff, C.A., Ayers, J.E., & Hill, R.R. (1988). Inheritance of resistance in gray leaf spot in corn (*Zea mays*) to gray leaf pot. *Phytopathology*, 78, 790-794.

Ivanovic, D., Levic, J., & Sataric, I. (1992). Inheritance of resistance to maize dwarf mosaic virus in some maize hybrids. *Maydica*, 37, 293-298.

Katwal, T.B. (2008). Gray leaf spot and Turcicum leaf blight epidemics in the high altitude areas of Bhutan p71. In: Book of Abstracts: The 10th Asian Regional Maize Workshop 20-23 October, 2008. Makassar, Indonesia. IAARD and CIMMYT.

Kim, S.K. (1994a). Genetics of maize tolerance of *Striga hermonthica*. *Crop Science*, 34, 900-907.

Kim, S.K. (1996b). Horizontal resistance: core to a research breakthrough to combat Striga in Africa. *Integrated Pest Management Reviews,* 1, 229-249.

Kim, S.K. (2000). Tolerance: An ideal Co-Survival Crop Breeding System of pest and host in nature with reference to Maize. *Korean J. Crop Sci*, 45, 59-71.

Kim, S.K., Efron, Y., Fajenisin, J.M., & Buddenhagen, I.W. (1989). Mode of gene for resistance in maize to maize streak virus. *Crop Science*, 29, 890-894.

Latterell, F.M., & Rossi, A.E. (1983). Gray leaf spot of corn: a disease on the move. *Plant Disease*,67,842-847.

Leonard, (1973). Folia pathogens of corn in North Carolina. *Plant Disease Reporter,* 58, 532-534.

Lipps, P.E. (1995). Gray leaf spot of corn. Pages 37-44 in: Proc. 7th. Annu. Iowa State Univ. Integr. Crop Manage. Conf. Ames.

Lipps, P.E., Thompson, P.R., & Pratt, R.C. (1996). Reaction of corn hybrids to gray leaf spot. Pages 163-189 In: Rep. Annu. Corn Sorghum Res. Conf., 51st.

Lipps, P.E., (1998). Gray leaf spot: A global threat to corn production. APSnet Feature (May). Published on line by The American Phytopathological Society, St. Paul, MN.

Manandhar, G. (2007). Gray leaf spot a threat to maize production in the hills of Nepal-in a quarterly news letter of Nepal Agricultural research Council 14 (4))Oct-Dec., Pp.4

Manh, N.Q. (1977). Inheritance of resistance to gray leaf spot in maize. M. S. thesis. Virginia Polytechnic Institute, Blacksburg,VA.Mathioni, S. M. Carvalho, d. C., Brunelli, K. R., Belo, A. Camarago L. E. A. 2006.

Menkir, A., & Ayodele, M. (2005). Genetic analysis of resistance to gray leaf spot of midatlitude maize inbred lines. *Crop Science*, 45,163-170.

Nowell, D.C. (1997). Studies on ear rot and gray leaf spot of maize in South Africa. Ph. D. Thesis. University of Natal, Pietermaritzburg 3200, South Africa.

Nutter, F.W. Jr., & Jenco, J.H. (1992). Development of critical point level yield loss models to estimate yield losses in corn caused by *Cercospora zeae-maydis* (Abstr.). *Phytopathology*, 82,994.

Okorai, P., Rubaihayo, P.R., Ekwamu, A., & Christina, D. (2004). Interactive effects of host, pathogen and mineral nutrition on gray leaf spot epidemics in Uganda. *European Journal of Plant Pathology*, 110,119-128.

Paudyal, K.R., Ransom, J.K., Rajbhandari, N.P., Adhikari, K., Gerpacio, R.V., & Pingali, P.L. (2000). Maize in Nepal: Production systems, constraints and priorities for research. Kathmandu: NARC and CIMMYT.

Paul, P.A., & Munkvold, G.P. (2005). Influence of temperature and relative humidity on sporulation of *Cercospra zeaze-maydis* and expansion of gray leaf spot lesions on maize leaves. *Plant Disease*, 89, 624-630.

Payne, G.A., Duncan, H.E., & Adkins, C.R. (1987). Influence of tillage on development of gray leaf spot and number of airborn conidia of Cercospora zeae-maydis, *Plant Dis.*, 71,329-332.

Payne, G.A., Duncan, H.E., & Adkins, C.R. (1987). Influence of tillage on development of gray leaf spot and number of airborne conidia of *Cercospora zeae-maydis, Plant Dis.*, 71, 329-332.

Payne, G.A., & Waldron, J.K. (1983). Over-wintering and spore release of *Cercospora zeae-maydis* in corn debris in North Carolina. *Plant Dis.*, 67,87-89.

Pinghali, P.L., & Pandey, S. (2002). Meeting worldwide maize needs: Technological opportunities and priorities for the public sector. Pages: 1-24 in: CIMMYT 1999-2000: (P. L. Pinghali ed.). Mexico D. F., CIMMYT.

Roane, C.W. (1950). Observations on corn disease in Virginia from 1947 to 1950. Plant *Dis. Rep.*, 34, 393-396.

Roane, C.W., Harrison, W., & Genter, C.F. (1974). Observation on gray leaf spot of maize Virginia. *Plant Dis. Rep*, 58,456-458.

Rupe, J.C., Siegel, M.R., & Hartmann, J.R. (1982). Influence of environment and plant maturity on gray leaf spot of corn caused by *Cercospora zeae-maydis*. *Phytopathology*, 72, 1587-1591.

Saghai-Maroof, M.A., Yue, Y.G., Siang, Z.X., Stromberg, E.L., & Rufener, G.K. (1996). Identification of QTL controlling resistance to gray leaf spot disease in maize. *Theor. Appli. Genet.*, 93, 539-546.

Shaner, G., Buechley, G., & Johnson, R. (1999). Effect of fungicide on seed corn, 1988. *Fungic. Nematic Tests*, 54, 355-358.

SHI, Li-yu, Xin-hai, L.I., Zhuanfrag, H.A.O., Chuan-xiao, X.I.E., Hai-lian, J.I., Xiang-ling, L.U., Shihuang, Z., & Guang-tang, P.A.N. (2007). Comparative QTL Mapping of 42.

Resistance to gray leaf spot in maize based on Bioinformatics. *Agri. Sci. China* 6(12), 1411-1419.

Singh, B.D. (2005). Plant Breeding: Principles and Methods. Kalyani Publishers, New Delhi.

Smith, C.M. (1988). History of benzimidazole use and resistance, In Fungicide resistance in North America, ed. C. J. Delp, pp 23-24. APS press, St. paul.

Smith, D.R., & White, D.G. (1987). Disease of corn. In: Corn and corn improvement monograph no.18, 3rd edition in the series AGRONOMY. American Society of Agronomy, Crop Science Society of America and Soil Science Society of America. Madison, Wisconsin, USA. pp. 687-749.

Smith, K.L. (1989). Epidemiology of gray leaf spot of field corn (*Zea mays* L.) caused by *Cercospota zeae-maydis* Tehon and Daniels, Ph. D. Thesis, University of Maryland.

Strange, R.N., & Scott, R.R. (2005). Plant Disease. A Threat to Global Food Security, *Annu. Rev. Phytopathology*, 43, 83-116.

Stromberg, E.L. (1986). Gray leaf spot disease of maize. Va. Co-op. Ext. Serv.Publ. 450-472. Virginia Polytechnic Inst. And State University, Blacksburg.

Stromberg, E.L., & Donahue, P.J. (1986). Hybrid performance of yield losses associated with gray leaf spot disease. pp. 92-104. In proc. 41st Corn Sorghum Res. Conf. American Seed Trade Assoc., Washington DC.

Stromberg, E.L. (2000). Gray leaf spot of corn. VCES Publication 450-612 (3 pages) on web at plant disease fs/450-612/450-612.

Tehon, L.R., & Daniels, E. (1925). Notes on the parasitic fungi of Illinois. *Mycologia*, 17, 240-249.

Thompson, D.L., Berquist, R.R., Payne, G.A., Bowman, D.T., & Goodman, M.M., (1987) Inheritance of resistance to gray leaf spot in maize. *Crop Science*, 27,243-246.

Thorson, P.R., & Martinson, C.A. (1993). Development and survival of Cercospora zeae-maydis germlings in different relative humidity environments. *Phytopathology*, 83:153-157.

Vanderplank, J.E. (1978). Genetic and Molecular Basis of Plant Pathogenesis. Springer Verlag, New York.

Verma, B.N. (2001). Gray leaf spot disease of maize- loss assessment, genetic studies and breeding for resistance in Zambia. Pages: 60-65 in: 7th Eastern and Southern Regional Maize Cong, 11-15th Feb 2001.

Wang , J., Levy, M ., & Dunkle, L.D. (1998). Sibling species of Cercospora associated with gray leaf spot of maize. *Phytopathology*, 88, 1269-1275.

Ward, J.M.J., & Nowell, D.C. (1998). Integrated management for the control of the maize gray leaf spot. *Integr. Pest Manage. Rev.* 3, 1-12

Ward, J.M.J. (1996). Epidemiology and management of gray leaf spot: A new disease of maize in South Africa. Ph.D. Thesis. University of Natal, Pietermaritzburg 3200, South Africa.

Ward, J.M.J., & Nowell, D.C. (1997). Epidemiology and management of gray leaf spot disease. A new disease of maize in South Africa. In Proc. 11th South Africa Maize Breeding Symposium Cedera, South Africa March 1994. Tech. Commun. Depart. Of Agriculture Tech. Services. Pretoria, South Africa.

Ward, J.M.J., Stromberg, E.L., Nowell, D.C., & Nutter , FW. Jr. (1999). Gray leaf spot: A disease of global importance in maize production. *Plant Disease*, 83,884-895.

White, D.G., Lipps, P.E., & Ayers, J.E. (1996). Gray leaf spot of corn. A report from NCR-25. Comitte on corn and sorghum disease. St. Louis, Ohio USA.

Wolf, E.D. (2002). Field crop disease facts. Gray leaf spot. College of Agricultural and cooperative extension, PENN STATE.

Wolfe, M.S. (1993). Can the strategic use of disease resistant hosts protect their inherent durability? In durability of disease resistant, ed. T. Jacobs JE Parleviets. Wageningen, Neth,: KIuwer.

Journal of Maize Research and Development (2015) 1(1):86-97
ISSN: 2467-9305 (Online)/ 2467-9291(Print)
DOI: 10.5281/zenodo.34283

Application of csm- ceres-maize model for seasonal and multi-decadal predictions of maize yield in under subtropical condition of Chitwan, Nepal

Lal Prasad Amgain*

ARTICLE INFO

Article history:
Received:
20th May, 2015
Revised :
12th July, 2015
Accepted:
5th November, 2015

Keywords:
CSM-CERES-Maize,
maize yield,
seasonal and multi-decadal yield prediction

ABSTRACT

The average maize yield of 2.5 t/ha in sub-tropical terai and inner terai of Nepal has been very less than its potential yield of about 5.0 t/ha, for which changing climatic scenarios have been reported the critical factors. Cropping system Model (CSM)-Crop Estimation through Resource and Environment Synthesis (CERES)-Maize, embedded under Decision Support System for Agro-technology Transfer (DSSAT) ver. 4.2 was evaluated from a datasets of field experimentation by growing four diverse maize genotypes viz. full season OPV (Rampur Composite), Quality Protein Maize (Posilo Makai-1), Hybrid (Gaurav) and Pop corn (Pool-12) under three different planting dates (September 1, October 1 and November 1) in 2009-10 at Rampur Campus, Chitwan. The experiment was laid out in two factor factorial randomized complete block design (RCBD) with three replications in slightly acidic (pH 6.7) sandy loam soil having low soil available N(0.49%) and K (148 kg/ha) and medium P (16.3 kg/ha) status. The ancillary and yield data obtaining from field experiment was analyzed from the M-Stat C software and recorded that Gaurav hybrid produced significantly higher yield under September 1 planting (5.86 t/ha) followed by Posilo Makai 1 (5.55 t/ha), Rampur Composite (5.1t/ha) and the least with Pool-12 (3.45 t/ha). Further, the heat use efficiency of diverse maize genotypes were also calculated by using the mean temperature based accumulative heat unit system and found the stable yields only with Rampur Composite for all planting dates and the rest genotypes were suitable only to the early winter plantings. Model calibration was done by using September 1 planting date for all 4 maize genotypes while validation was accomplished by using the remaining treatments for predicting growth and yield of different maize genotypes. The year 2006- 07 was found 13, 18, 23 and 7% higher in producing the maize yield than the standard year 2009-10 for Rampur Composite, Posilo Makai-1, Gaurav and Pool-12, respectively. Further, the different climate change scenarios as advocated by IPCC (2007) for 2020, 2050 and 2080 from base line of 2009-10 was studied to simulate the growth and yield performance of diverse maize genotypes with September 1 planting date and found that there would be increment in winter maize yield up to 2020 scenario of climate change and the drastic yield loss would be on 2050 to 2080 scenarios under the present levels of agronomic management options and urged for the new climate change adaptation and mitigation production technologies.

INTRODUCTION

Maize (*Zea mays* L.) is the second most important staple food crop after rice in terms of area and production in Nepal (Adhikari, 2007) and third among major cereal crops in the world with the 146.7 m ha global areas and production of 699 m tones (Gupta *et al*., 2010).

Corresponding author Info:
**Asst Prof Agronomy,*
Institute of Agriculture and Animal Science, Sundarbazaar, Lamjung, Nepal
E-mail- amgainlp@gmail.com

In the sub-tropical Nepalese terai and inner-terai including Chitwan, Bara, Parsa, Rupandehi and Nawalprasi districts are becoming popular for growing winter maize and the area under it has been increasing over the years with the depletion of mustard and wheat yields (MoAC, 2009). The higher yield of winter maize is the main reason for its easy and rapid adaptation and its coverage area is about 20-25% of total maize area in Nepal (Gurung, 2010). It has also been reported that the overall demand for maize will be increased by 6-8% per annum largely for the next two decades as a result of increased demand for food in hills and feed in terai, inner terai and this increased demand could only be met by increasing the productivity of maize per unit of land (NMRP, 2009).

Proper selection of planting time and genotypes play a key role in growth and development of growing crops. If matching properly, it ensures the adequate temperature for germination and growth, avoid extreme temperatures that could cause stress or difficulty in setting and developing seeds, provide adequate moisture for growth and completing life cycle of any crop and minimize other stresses during the growing period. But, due to the intensive cultivation practices (>300 % cropping intensity) in the major domain areas of terai and inner-terai of Nepal, winter maize planting time sometimes gets delayed due to the late harvest of the preceding crop or lack or surplus rainfall during September. Delayed planting particularly in late October to December, results poor yield due to low temperature induced delayed germination and slow vegetative growth Similarly, very early planting in late August or early September is not conducive to the maize growth and yields because of negative consequences of higher temperature and rainfall at the initial growth stages (NMRP, 2004). NMRP has already recommended more than two dozen varieties of maize in Nepal (NMRP, 2009) suited for different agro-ecological zones of Nepal of which the inbred maize cultivar Rampur Composite having potential yield of 5.0 t/ha has attainable yield of only about 3.5 t/ha, but the actual yield in farmer's field is far less i.e. 1.9 t/ha (NMRP, 2004). The specialty maize cultivars like hybrids, quality protein maize (QPM) and pop corns are the new diversification on maize plantings. The QPM seeds are the recent advancement in maize breeding in Nepal, where the cereal lacking amino-acids Lysine and Tryptophan can also be available. The protein profile of QPM maize is much better and it is 90% of milk protein while to the other maize it is only 40% (Gupta *et al*., 2010). Gaurav, the single Nepalese hybrid genotype has very high potential yield of 9.0 t/ha with actual yield of 5.5 t/ha, however, could not become popular over the Indian hybrids in farmers field. Pop corns, the common snack item is a special maize group characterized by dwarf stature and high N requirement and are gaining momentum on these days and hence its' productivity should also be increased with different agronomic approaches (Banerjee and Singh, 2003). Research addressing the issue of yield gaps and identifying factors responsible for these gaps is important both for increasing food security and national revenue generation as well as for increasing resource use-efficiency and sustainability. From several researches, it has also been reported that hybrids can give 20-50% more grain yield than the inbred variety (Masthana *et al*., 2001, Gupta *et al*., 2010). But, the hybrid and improved cultivars of any crops are more sensitive to the environment of climatic variability than the local genotypes and yield reduction is more on them (Lamsal and Amgain, 2010; Bhusal *et al*., 2009). Hence, empirical investigation on the real magnitude on yield loss of most prominent genotypes should be known to harvest optimum yield. The inter-governmental panel on climate change (IPCC) has projected that the global mean surface temperature is predicted to rise by 1.1 – 6.4 ^{0}C by 2100 with the different amplitudes of

temperatures and CO_2 for different scenarios of 2020, 2050 and 2080 (IPCC, 2007). IPCC (1996) has also projected the increase in mean temperature by 0.4 to 2.0 ^{O}C during monsoon and 1.1- 4.5 ^{O}C during winter by 2070. The recently advanced climatic adverseness could bring increase in CO_2 concentration, increase or decrease rainfall amount and intensity, change in solar radiation including global dimming, temperature variations and variations in relative humidity etc, as a whole the global climate change is negatively affecting the crop growth and yield in general. These all have also been common in Nepal and will have an adverse affect on Nepalese agriculture (Malla, 2008). Increase in CO_2 concentration brings increase in temperature and ultimately decrease the crop yield by reducing the crop growth duration. Climate change via increasing atmospheric concentration of CO_2 can affect global production of the C_4 crops like maize through change in photosynthesis and transpiration rates and ultimately lower production. The beneficial effect of 700 ppm CO_2 would be nullified by an increase of only 0.9^{0}C in temperature (Chatterjee *et al.*, 2003). There is an immense potential to capitalize the proportion of un-harvested yield and now research has to focus for alternative technological approaches to break this yield barrier. With the advancement of the applied science, different types of crop models have been evolved. Among them, DSSAT ver. 4.0 is one which can help to investigate a range of issues from crop management (Jones *et al.*, 2003). The CSM-CERES-Maize can estimate the seasonal and sequential trend analysis for the long-historical periods and cropping sequences (Jones *et al.*, 2003) and its scope has been widened recently. The CSM-CERES-Maize embedded in DSSAT model (version 4.2) has not been tested over a wide array of location except a very few locations in Nepal (Sapkota et *al.*, 2008; Bhusal *et al.*, 2009) but found satisfactory. Further testing of this version covers the sub-tropical climate of Nepal and will be a highly valued scientific work for proper decision making especially with regards to winter season maize. Hence, this concurrent field and simulation modeling studies was done to find out the optimum time of planting to cope up with the climatic adverseness for different diverse maize genotypes and to simulate the effect of changing climatic scenarios and multi-year attributable predictions on growth, phenology and yields of various prominent maize genotypes grown under sub-tropical environment of central Nepal.

MATERIALS AND METHODS

Field experimentation

A field experiment consisting of the combination of the four diverse maize genotypes {full season OPVs (Rampur Composite), Quality Protein Maize (Posilo Makai 1), Hybrid (Gaurav), and Pop corn (Pool-12)} with three different planting dates (September 1, October 1 and November 1) was accomplished at the Agronomy Farm of Rampur Campus, Chitwan during winter season of 2009-10 representing the sub-tropical climate of terai and inner terai. The experiment was carried out in two factor factorial randomized complete block design having three replications. The soil of the experimental research site was sandy loam in texture and slightly acidic (pH 6.7) in reaction. Total nitrogen and soil available potassium was found to be lower (0.49% N and 148 kg K/ha, respectively) in surface soil profile, but soil available phosphorous was found to be of medium (16.3 kg/ha) level and most of all parameters were found decreasing with increasing profile depth up to 1 m depth. The maximum and minimum temperatures, sunshine hours and rainfall data during the cropping periods and historical weather records were collected from the National Climatic Observatory of National Maize Research Program. The maize crops were grown with the principle of yield maximization by providing the recommended packages of practices (Reddy, 2009). The various ancillary, phenology and yield data obtaining from field experiment was analyzed with the M-Stat-C

software and mean data was further subjected to model evaluation under the sub-tropical environment of central southern Nepal. The agro-climatic indices like growing degree days (GDD) and heat use efficiency were calculated and expressed to identify the best agro-climatic indices for different cultivars of maize.

Model evaluation and application

The data were taken in consideration to making appropriate input files (file X, file A, file T, Soil file and Weather file) required for CSM-CERES-Maize ver. 4.2. Model evaluation was done by standard model procedures on various climate change factors to simulate the growth and yield performance of diverse maize genotypes with September 1 planting treatment. At first, the model was calibrated by using the best performing treatments (September 1 planting date for all four diverse maize genotypes), while validation was accomplished for the remaining eight treatments over the ancillary parameters viz. days to anthesis and physiological maturity, above ground biomass at harvest, unit grain weight and grain yields. Moreover, simulation to different scenarios of climatic parameters was accomplished by comparing the growth and yield performance of maize genotypes for various weather years (2005-06 to 2008-09). The proportionate increase or decrease in maximum and minimum temperature, solar radiation and increase of CO_2 concentration on the input file (File-X) of maize was done by changing their respective magnitude to predict the growth and yield performance of maize as advocated by IPCC (2007) for 2020, 2050 and 2080 scenarios. The scenarios given are in the range of increase of 2-4^0 C temperatures and of CO_2 concentration of 420 to 570 ppm for those periods, respectively (Abdul Haris, 2010).

RESULTS AND DISCUSSIONS

Grain yield and yield gaps in maize

The grain yields of Rampur Composite (4.18 t/ha), Poshilo Makai-1 (4.47 t/ha) and hybrid (Gaurav) genotypes (4.71 t/ha) were significantly higher than Pool-12 genotype (2.63 t/ha) but, the Poshilo Makai-1 was statistically at par both with Rampur Composite and Gaurav (Table 1).

Table 1. Grain yield of different diverse maize genotypes as influenced by planting date at IAAS, Rampur, Chitwan

Treatment	Grain yield (t/ ha)			
	Planting dates			Mean
Maize genotypes	September 1	October 1	November 1	
Rampur Composite	5.10	4.0	3.43	4.18
Poshilo Makai-1	5.55	4.27	3.64	4.47
Gaurav	5.86	4.45	3.83	4.71
Pool-12	3.45	2.42	2.02	2.63
Mean	4.98	3.79	3.23	
$LSD_{(0.05)}$ (Genotypes)		0.680		
$LSD_{(0.05)}$ (Planting dates)		0.922		
$LSD_{(0.05)}$ (Interaction)		NS		

Higher grain yield of all composite, QPM and hybrid was because of higher number of kernel rows and number of kernels and test weight resulting from higher dry matter and LAI as compared to Pool-12 which obviously was a small seeded and earlier cultivar. Walker *et al*. (2008) has also reported 17 to 20% higher yield in hybrid than the inbred cultivars. The grain

yield of maize due to planting time was significant only for September planting and this might be due to higher thermal units (heat use efficiency) taken by all the maize varieties.

Table 2. Grain yield observed (t/ha) and yield reduction due to delayed planting in different maize cultivars

Maize cultivars	Grain yield (t/ha)			Yield reduction (%) due to late sowing		
	Sept 1	Oct 1	Nov 1	Sept vs Oct	Oct vs Nov	Sept vs Nov
Rampur Comp.	5.1	4.0	3.43	21.52	14.25	32.75
Posilo Makai-1	5.50	4.27	3.64	22.36	14.75	33.82
Gaurav	5.86	4.45	3.83	24.06	13.93	34.46
Pool-12	3.45	2.42	2.02	29.86	16.53	41.45

The date of planting is major governing factors in crop production and it is considered to be low-cost and high monetary returning management practices. For a condition of sudden rise in ambient temperature and CO_2 concentrations, the changes in variety and planting time could be the best adaptive measures to minimize the yield loss. September planting maize has been producing higher yield than the subsequent late plantings. The percentage reduction in yield was high for September versus (*vs*) October planting than the October *vs* November planting and the highest for Sept *vs* November planting (Table 2) in all the maize cultivars. Late planting was negatively affected by low temperature longer from the initiation of heir early vegetative growth, which reduced the major sources and sinks and thus resulted more yield gaps. Rao and Singh (2007) have also recorded the fewer yields of course cereals including pearl millet when planted delayed in Rajsthan, India.

Heat use efficiency and stability of maize yield

From the result (Table 3) it was observed that all maize cultivars were more efficient to show higher heat use efficiency on normal planting condition than their subsequent late plantings.

Under 1st September planting condition, Gaurav had markedly higher HUE (3.46) followed by Posilo Makai 1 (3.30), Rampur Composite (3.03) and the lowest with Pool-12 (2.13).

Table 3. Heat use efficiency (HUE) of different maize cultivars as affected by planting time

Maize cultivars	Heat use efficiency (HUE)			Reduction (%) due to late sowing		
	Sept 1	Oct 1	Nov 1	Sept *vs* Oct	Sept *vs* Nov	Oct *vs* Nov
Rampur Comp.	3.03	2.94	2.44	3.29	19.73	17.0
Posilo Makai-1	3.30	3.19	2.53	3.33	22.33	20.68
Gaurav	3.46	3.13	2.60	9.83	24.86	16.67
Pool-20	2.13	1.90	1.66	10.38	21.70	12.63

At both of the late planting conditions all the cultivars significantly reduced their HUE in various magnitudes compared to normal growing condition by following the same trend as that of normal planting. The reductions in HUE for maize cultivars planted late were higher for September *vs* November planting than the October *vs* November planting and the least with September *vs* October planting. The decrease in HUE due to late sowing was due to sensitiveness of variety to the adverse cold temperature and found to be higher in Gaurav Hybrid (24.86%) followed to Posilo Makai-1 (22.33%), Pool-12 (21.70%) and the least with Rampur Composite (19.73%) in between September v*s* November planting. The similar

trend was also noticed for September *vs* October planting too, however their effects were quite smaller. Rampur Composite has less reduction in HUE amongst all the planting date. Hence, it can be concluded that Rampur Composite is the best for timely and for late winter planting too. The specialty corn cultivars QPM (Posilo Makai-1), hybrid (Gaurav) and Pop-corn (Pool-12) have not shown the stability in HUE. In spring and winter maize the same result has been noted by Amgain (2011). Paul and Sarker (2000) have also reported the similar result on late planted wheat in Bangladesh.

Model evaluation

Model parameterization

The following genetic coefficients for all four diverse maize genotypes were adjusted by running the models several times by trial and error methods (Table 4). The model calibration was accomplished by adjusting the proximity values between observed and simulated values on 75% dates of anthesis, and physiological maturity and adjustable grain yield for all four maize cultivars planted on 1 September by changing the values of genetic coefficients (P_1, P_2, P_5, G_2, G_3 and PHINT). The observed anthesis days of 63, 66, 68 and 60 days was first brought to proximity by making the changes in P_1 and P_2 values and physiological maturity dates of 135, 136, 138 and 123 days with changing in the values of P_5 to Rampur Composite, Posilo Makai-1, Gaurav and Pool-12 cultivars of maize, respectively. The adjustment in observed grain yield of 5100, 5500, 5860 and 3450 kg/ha, respectively for above mentioned genotypes in succession was done by changing the values of G_2, G_3 and PHINT and tried to come to proximity between the observed and simulated grain yield. The simulated anthesis

physiological maturity was 134, 136, 138 and 123 days and grain yield was 5260, 5680, 5920 and 3540 kg/ha, respectively. The results obtained were found to be slightly over-estimated but within the range of 10 per cent which normally be accepted.

Table 4. Estimated genetic coefficients of maize genotypes under different planting dates during 2009-10 at Rampur, Chitwan, Nepal

Maize genetic co-efficient	Rampur Composite	Posilo Makai- 1	Gaurav	Pool-12
Thermal time from seedling emergence to end of juvenile phase (P_1)	250	300	275	240
Extent of development days to get the days adjusted in this model param was 63, Rampur Mal Composite, Posilo Gau optimum photoperiod (P_2)	0.60	0.65	0.70	0.50
Thermal time from silking to physiological maturity (P_5)	850	860	875	760
Maximum possible number of kernels/plant (G_2)	650	720	700	620
Kernel filling rate (mg/day) (G_3)	7.50	8.75	10.50	8.00
Phyllochron interval (PHINT)	45	50	55	40

Model Validation

Statistical results in maize showed good agreement between observed and predicted grain yield (RMSE = 257.8 kg/ha and D-index = 0.96), test weight of grain (RMSE of 0.008g/kernel and D-index of 0.89) anthesis days (RMSE = 1.0 day and D-index = 0.86) and maturity days (RMSE = 1.56 days and D-index = 0.82). However, biological yield at maturity showed fairly satisfactory agreement (RMSE = 2475.15 kg/ha and D-index = 0.68) between observed and simulated values as simulated values were over-predicted to all observed yields with acceptable level. Most of the tested parameters showed valid result except some of the discrepancies and that might be due to the variations in initial soil nitrogen status indicating low to moderate soil fertility as it was found in the research field.

Sensitivity to weather years

CERES-Maize was found to be sensitive to weather years and recorded that year 2006-07 was best for all the maize cultivars in which Rampur Composite, Posilo Makai-1, Gaurav and Pool-12 recorded about 13, 18, 23 and 7 percent higher yield than the base year 2009-10, respectively (Table 5). This might be attributed to the better sunshine hour recorded in the year 2006-07 and the winter rainfall was also well-distributed and higher than the other years. This decline in the yield for the rest of the years under simulation study was due to the slightly lower temperature resulting from the less solar radiation and irregular and minimum rainfall in those particular years. This sort of simulation study of the past years highlighted that maize crop is sensitive of weather parameters and basically the lowering winter temperature with global dimming is causing the lower maize yield and some adaptation measures like changes in planting dates and cultivars should be followed to harvest the optimum maize yield. Such sort of trend may be repeated in the future and this will make the crop growers to follow early warning system.

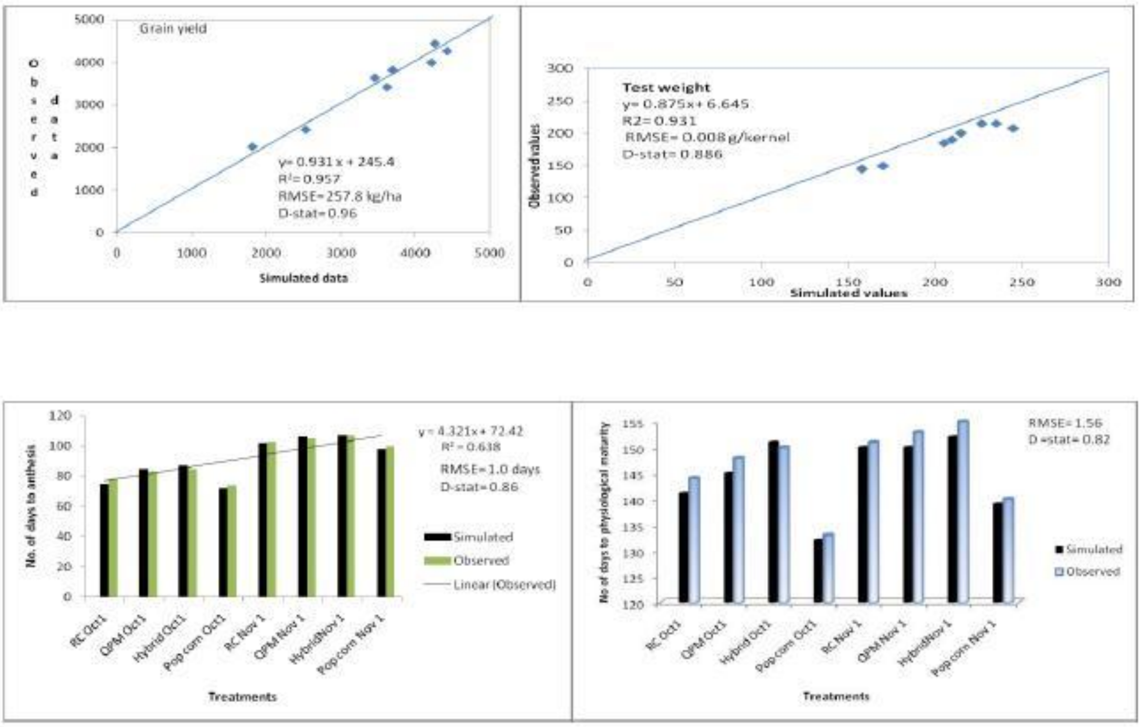


Figure 1. Simulated and observed grain yield (kg/ha), unit grain weight (g), anthesis days and physiological maturity days for four maize cultivars

Table 5. Sensitivity of simulated yield and phenology of maize cultivars to weather years with September 1 planting date

Maize varieties	Weather years	Simulated yield (kg/ha)	Percent yield	Anthesis (days)	Physiological maturity (days)
	2009-10 [a]	5260	100	63	134
Rampur Composite	2008-09	5103	97	62	133
	2007-08	5680	108	64	135
	2006-07	5942	113	64	136
	2005-06	5523	105	63	134
Posilo Makai-1	2009-10 [a]	5680	100	65	136
	2008-09	5395	95	64	135
	2007-08	6410	113	65	137
	2006-07	6705	118	66	138
	2005-06	6190	109	65	136
Gaurav	2009-10 [a]	5920	100	68	138
	2008-09	4915	83	67	136
	2007-08	6864	116	69	139
	2006-07	7282	123	70	139
	2005-06	6512	110	68	138
Pool-12	2009-10 [a]	3540	100	60	123
	2008-09	3295	93	60	121
	2007-08	3682	104	60	123
	2006-07	3785	107	61	124
	2005-06	3610	102	60	123

[a] Standard years

Sensitivity to climate change parameters and multi-year prediction

The model was sensitive to various scenarios of climate change parameters (temperature, solar radiation and CO_2 concentrations). Change in maximum and minimum temperatures upto 2^0 C (+ 2^0C) and CO_2 concentrations upto 420 ppm (+50 ppm) with change in solar radiation (+1MJ m^{-2} day^{-1}) resulted maximum increase in yield of Rampur Composite, Posilo Makai, Gaurav and Pool-12 by 11, 12, 13 and 15 percent (Table 6) while the maximum increase in the maximum and minimum temperatures by 4^0 C along with 100 and 200 ppm CO_2 concentration showed the yield decline of 28, 35, 42 and 22 percent each to Rampur Composite, Posilo Makai-1, Gaurav hybrid and Pool-12 than the standard model treatment (without changing the weather parameters). This reflected that the hybrids are more sensitive to the adverse climatic variability. The existing varieties of maize could not sustain the yield potential of the present level in future after 2020 and hence it should be opined to adopt the climate change adaptation or mitigation strategies over the long-run. Increased CO_2 concentrations would reduce transpiration and nutrient losses and increase water, nutrient and radiation use efficiencies and that might have increased yield under decreasing temperature. Similar result was also resulted by Bhusal *et al.*, (2009), Singh and Padilla (1995). The maize being C_4 crop it can take advantage of lower concentration of CO_2 which could not be possible in C_3 crop plants. Even though increase in ambient CO_2 does not have significant direct effects on C_4 (C_4 carbon fixation pathway) photosynthesis of maize crop (Leakey *et al*. 2004, 2006), increase in ambient CO_2 leads to higher water use efficiency in water stress conditions and thereby influences dry matter production and grain yield (Byijesh *et al.*, 2010). But the increasing temperature will make it negatively affecting. Several studies have revealed the temperature sensitivity of maize. High temperature hastens the crop phenology; doubling temperature variability can reduce the maize yield upto 50% (Wheeler *et al.*, 2000).

Table 6. Sensitivity analysis of different maize genotypes as according to the different climate change scenarios for 2020, 2050 and 2080

S. No	Max temp (°C)	Min temp (°C)	SR (MJ/m²/day)	CO_2 conc. (ppm)	Treatments	Simulated yield (kg/ha)	% yield change	Growth duration (days)
1 [a]	+0	+0	+0	370	Rampur Comp.	5260		134
					Posilo Makai-1	5680		136
					Gaurav	5920		138
					Pool-12	3540		123
2	+1	+1	+0	370	Rampur Comp.	5465	+4	134
					Posilo Makai-1	5920	+4	135
					Gaurav	6355	+7	137
					Pool-12	3820	+8	122
3	+1	+1	+1	+ 50	Rampur Comp.	5645	+7	134
					Posilo Makai 1	6150	+8	135
					Gaurav	6545	+8	136
					Pool-12	3935	+11	122
4	+2	+2	+1	+ 50	Rampur Comp.	5820	+11	133
					Posilo Makai-1	6235	+12	134
					Gaurav	6675	+13	136
					Pool-12	4055	+15	122
5	+3	+3	+1	+ 100	Rampur Comp.	4505	-6	133
					Posilo Makai-1	5154	-9	134
					Gaurav	5320	-10	136
					Pool-12	3357	-5	121
6	+3	+3	+1	+ 200	Rampur Comp.	44085	-14	133
					Posilo Makai-1	4725	-17	134
					Gaurav	4565	-23	136
					Pool-12	3070	-13	121
7	+4	+4	+1	+ 200	Rampur Comp.	3785	-28	131
					Posilo Makai-1	3650	-35	132
					Gaurav	3430	-42	133
					Pool-12	2760	-22	120

Note: 1[a] : Standard climatic conditions (model default), 2, 3 & 4: Climate change scenario 2020, 5 & 6:. Climate change scenario 2050 and 7: Climate change scenario 2080 as given by IPCC (2007).

CONCLUSION

To achieve the higher productivity and increasing demand of the maize, there should follow the climate change adaptation studies especially for open pollinated Composite breeds and specialty maize like, Hybrids, QPM and Pop corn. T*he* CSM-CERES-Maize Model was well validated under the sub-tropical condition of central southern *Nepal* and has shown the immense scope of using this model as a tool for estimating yield gaps and study on different scenarios of climate changes. For wider application of models and using it for better decision support system, there is a real need of further testing and verification of model in large agro-ecological areas of Nepal.

ACKNOWLEDGEMENTS

The author is highly thanked to Nepal Academy of Science and Technology (NAST) for providing financial supports for the accomplishment of this research work. NMRP is thanked for providing agro-meteorological data sets to run the model.

REFERENCES

Abdul, H., Biswas, A.S., & Chhabra, V. (2010). Climate change impacts on productivity of rice (*Oryza sativa*) in Bihar. *Indian Journal of Agronomy*, 55 (4), 295-298.

Adhikari, K. (2007). Maize in Nepal: Research Achievements (2004-2006) for food and feed security and livelihood improvement. Pp 1-6. In: D B. Gurung. D. C. Paudel, G., K. C., S. R. Upadhya and B. B. Pokharel (eds). Proceedings of the 25th National Summer Crops Research Workshop on Maize Research and Production in Nepal, held on June 21-23, 2007 p. 2.

Amgain, L.P. (2011). Accumulated heat unit and phenology of different maize cultivars as influenced by planting time and seasons. *J. Inst. Agric. Anim. Sci.* 31&32**,**143-150.

APP. (1995). Agricultural Perspective Plan of Nepal. MoAC, GoN, Singhaarbar, Kathmandu, Nepal.

Banerjee, M., & Singh, S. N. (2003). Effect of N and plant population on yield components and yield of pop-corn varieties of maize. *Annals of Agri. Res. New Series* 24 (4), 968-970.

Bhusal, T. N., Amgain, L.P.,& Devkota, N.R. (2009). Evaluation of CSM-CERES-Maize model and sensitivity analysis of open pollinated varieties of maize at Rampur Chitwan. *J Inst. Agric. Anim. Sci.* 30, 63-72.

Byjesh, K., Naresh Kumar, S., & Aggarwal, P.K. (2010). Simulating impacts, potential adaptation and vulnerability of maize to climate change in India. *Mitig Adpt Strateg Glob Change* ,**15**, 413-431.

Chaterjee, A., Pathak, H., Soni, U. A., & Kalra, N. (2003). Impact of climate change on Indian agriculture. Soil and Green house effect Monitoring and Mitigation. CBS Publishers and Distributors, Bangalore. 86-95.

FAOSTAT. (2007). Agriclture data (online). In: www.fao.org. Available at http://faostat.org (last update 2007; assessed 19 Nov, 2007). Rome Italy: Food and Agriculture Organization (FAO).

Gupta, H. S., Mahajan, V., Agarwal, P.K., Bist, G.S.,& Pant, M.C. (2010). Vivek QPM9 maize: a hybrid for Himalayan hills and Peninsular region. *Indian Farming*, 59 (11), 10-12.

Gurung, D. B. (2010). National Co-ordinators' Report on Maize: Paper presented in the 26th Summer Crop Workshop at Rampur Chitwan, Nepal (3-5 March, 2010).

IPCC. (2007). Climate Change 2007: Climate Change Impacts, Adaptation and Vulnerability. Summary for Policy Makers. Inter-Governmental Panel on Climate Change. II Assessment Report of the Intergovernmental Panel on Climate Change. Watson, R. T., M C. Zinyowera, M. C. and R. H. Ross (Eds), Cambridge and New York, p 880.

Jones, J. W., Hoogenboom, G., Porter, C.H., Bootee, K.J., Batchelor, W.D., Hunt, L.A., Wilkens, P.W., Singh, U.A., Gijsman, J., & Ritchie, J.T. (2003). The DSSAT Cropping System Model. *European Journal of Agronomy* ,18, 235-265.

Lamsal A., & Amgain, L.P. (2010). Simulation of growth and yield of rice under varied agronomic management and changing climatic scenarios by using DSSAT ver. 4.0 Crop Model in Chitwan, Nepal. *Indian Journal of Hill Agriculture Research*, 1 (2), 26-35.

Malla, G.S. (2008). Climate change and its impact on Nepalese agriculture. *The Journal of Agriculture and Environment* , 9, 62-71.

Masthana Reddy, B.G., Pattar, P.S.,& Malabasari, T.A. (2001). Response of rice (*Oryza sativa*) hybrids to organic manures and inorganic fertilizers. *Indian J. Agric. Sci.,* 71(11),713-714.

MoAC. (2009). Selected indicators of Nepalese agriculture ad population. Government of Nepal. Ministry of Agriculture and Co-operatives. Agric-business Promotion and Statistics Division, Singhdarbar , Kathmandu, Nepal.

NMRP. (2004). Annual Report, National Maize Research Program, Rampur Chitwan, Nepal.

NMRP. (2009). Annual Report, National Maize Research Program, Rampur Chitwan, Nepal

Pual, N.K.,& Sarker, D. K. (2000). Accumulated heat units and phenology relationships in wheat as influenced by sowing dates. *Bangladesh J. Bot.* 29(1), 49-54.

Sapkota, A., Amgain, L.P., Devkota, N.R.,& Timsina, J. (2008). Evaluation of CSM-CERES-Maize model, estimation of potential yield and yield gap analysis of winter maize at Rampur, Chitwan. *J. Inst. Agric. Anim. Sci*., 29, 27-32.

Singh, U. & Padila, J.L. (1995). Simulating rice response to climate change. In: Climate Change and Agriculture: Analysis of Potential International Impacts. ASA Special Publication Number 59. ASA Madison, Wisconsin. pp. 99-122.

Walker, T.W., Jason, A.B., Ottis, B., Patrick, V., Dustin, D.G.,& Harrell, L. (2008). Hybrid rice response to nitrogen fertilization for Mid-southern United States rice production. *Agron J.*,100, 381-386.

Wheeler, T.R., Craufurd, P.Q., Illis, R.H., Porter, J.R., & Vara Prasad, P.V. (2000). Temperature variability and the yield of annual crops. *Agric. Ecosyst. Environ*, 82, 159-167.

Journal of Maize Research and Development (2015) 1(1):98-105
ISSN: 2467-9305 (Online)/ 2467-9291 (Print)
DOI: 10.5281/zenodo.34288

Survey on maize post-harvest losses and its management practices in the western hills of Nepal

Ghanashyam Bhandari[1]*, Buddhi Bahadur Achhami[1], Tika Bahadur Karki[1], Balram Bhandari[1] and Gopal Bhandari[1]

ARTICLE INFO

Article history:
Received:
11th September, 2015
Revised :
12th October, 2015
Accepted:
16th November, 2015

Keywords:
Maize, Weevil, Infestation, Storage, Post-harvest losses

ABSTRACT

A survey was conducted in order to assess the losses of maize under farmers' storage conditions in the Western hills of Nepal in 2014. The survey area included Thanapati Village Development Committee (VDC) of Gulmi, Aalamdebi VDC of Syangja, Khasauli VDC of Palpa and Baglung municipality-12, Baglung district. Primary information was collected through semi-structured questionnaires among the heterogenous groups of the farming communities. Survey revealed that about 61% respondents reported the storage pest as the major pests and about 12% respondents reported that field pests as the major pests in the western hills. Maize weevil (*Sitophylus zeamais* Mostsch.) and Angoumois grain moth (*Sitotroga cerealella* Oliv.) were found to be major storage insect pests in surveyed areas. Majority of respondents (39%) presumed on 10-20% losses during storage. Among the other biotic factors, farmers ranked insect (42%), weeds (32%) and diseases (17%) respectively. Maize storage methods had distinct among the surveyed areas compared with Baglung district to other surveyed areas. In Baglung, about (73%) farmers had stored maize in the form of grain whereas in Palpa, Gulmi and Syangja, about (77%) farmers had practice of storing maize with husk for 5-7 months. Approximately, 40% respondents were using open floor in upper stair "Aanti"as a major maize storage place in Palpa, Gulmi and Syangja whereas almost (79%) of respondents were using sacks to store shelled grains in Baglung. Hence, there is ample opportunity to reduce the storage losses of maize depending upon the existing situation.

INTRODUCTION

Maize (*Zea mays* L.) is the second most important staple food crop after rice and a major food crop in the hills of Nepal (Upadhyay *et al.*, 2007). In tropical developing countries, a large proportion of the maize crop is harvested under humid and warm climatic conditions and most small farmers lack equipments for drying grains (Mettananda *et al.*, 2001). Apart from other factors, insect/pests and diseases have been playing a significant role in reducing

Corresponding author Info:
1National Maize Research Program
Nepal Agricultural Research Council
*Email: bhandarigb_1978@yahoo.com
bhandari.ghanshyam@narc.gov.np

production and productivity coupled with germination potential (Manandhar and Shivakoti, 2000).Among insect pests, maize weevil (*Sitophyllus zeamais*) and Angoumois grain moth (*Sitotroga cerealla*) were the most important insects in stored maize in Nepal (Sherpa *et al.*, 1997, G.C., 2006). Post-harvest losses were particularly problematic under the maize-based system in the hills of Nepal (Ransom, 2000). The storage of shelled grains is not a common practice in the Eastern hills. Majority of households in Eastern region store maize ears (cobs) on vertical wooden or bamboo frames outside the house (Thangro/Suli) and some households store the maize ears inside the upper room or loft of their houses, the ears being heaped into a regular shape with no material support (Kuniyu) (Bajracharya *et al.*, 2007). In general, maize was stored on Thankro/Suli, hanging on ropes, Kuniyu, and Dehari (Manandhar and Shrestha, 2000). K.C. (1992) reported that in Nepal, post-harvest losses in cereals was about 15-20%. Pradhan and Manandhar (1992) reported that the losses in storage were 8%, 7.4% and 13% respectively in Mountain, Hills and Terai of Nepal. Boxal and Gillet (1980) recorded 5.5 % average weight loss due to weevil attack in the Eastern hills of Nepal. Khanal *et al.*(1990) estimated maize storage loss of 10.6% due to weevils in Pakhribas conditions. However, Paneru *et al.* (1993) found storage losses of up to 32% due to the maize weevil. Similarly, based on the examination of several maize cobs stored in a Thangro for a period of 8 months, Golob (1994) found infestation levels of between 50 to 100% by *Sitophilus* weevils. Manandar and Mainali (2000) reported that insect incidence was highest in Thangro/Suli as compared to other structures. Ghimire *et. al.* (1996) indicated that the loss in terms of weight of up to 20% in a typical post-harvest storage situation. According to Sah (1998) the level of weevil infestation varied from 51.1 to 97 .0% in the mid altitude (1500 masl) to low altitude (750 masl) irrespective of yellow or white maize when stored in a Kuniyu (heaping of cobs) for a period of 5 months. Shivakoti (1981) reported an infestation level of up to 49% by *Sitotroga cerealella* and weevils stored in Thangro/Suli for a period of 6 months. The weight loss varied from less than 1 to 6% in different years. Pradhan and Manandhar (1992) reported the total loss of cereal grain from rodents was 44.3% on a national basis and in maize alone is about 21.5 % in the mountains, hills and terai regions. The post-harvest molds such as *Penicillin* and *Aspergillus* also cause about 1 to 5% losses in maize depending upon the time of maize harvest, duration of storage and it's conditions (Manandhar and Batsa, 2000). These molds besides deteriorating the grain also produce aflatoxin which would carcinogenic to man and animals. The majority of farmers and concerned organizations are tend to concentrate their efforts on the production aspect. While focusing on production, farmers tend to ignore the need for post-harvest loss minimization (Aulakh and Regmi, 2013). Gyawali (1993) reported that 50 plant species available in Nepal against insect pests in crops and stored grains. Among these plants, sweet flag stolen *(Acorus calamus*), neem *(*Azadirachta indica),oil, neem seed powder, timur (*Zanthoxylum armatum)*, titepati *(Artimesia vulgaris)* have been reported to be superior in controlling the maize weevils (Paneru *et. al.*, 1996). Thus, this survey was designed to assess recent trend of maize grain losses during storage in hills of Nepal.

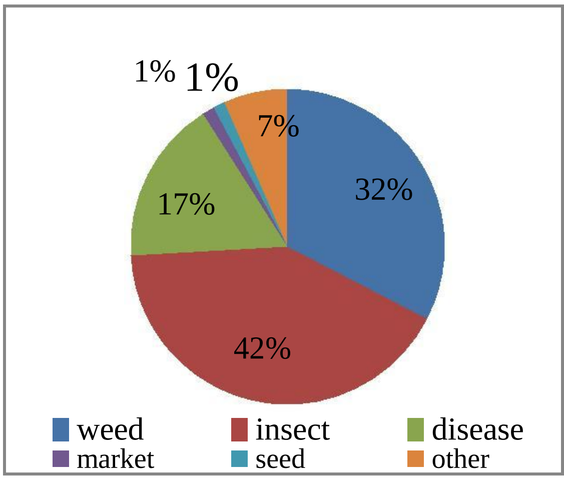
METHODOLOGY

The study was carried out in the mid hill districts of Thanapati VDC, Gulmi, Aalamdebi VDC, Syangja, Khasauli VDC, Palpa and Baglung municipality-12, Baglung. A total of 89 households and 4 different Community Based Seed Production (CBSP) groups were involved in the study. Primary information was collected through using semi-structured questionnaires among the heterogeneous groups of the farming communities. Key informants were interviewed directly visiting the individual household and focus group discussion was carried out with CBSP groups through using checklists. Available information on issues related to post harvest losses on maize during the period of the survey were study at best. Furthermore the information was based on interviews with farmers and not on actual measurements. Pair-wise ranking of each location regarding the post-harvest handling to maize grain storage and losses were comprised subsequently.

RESULTS AND DISCUSSION

1. Major problem in the maize field

Survey report revealed that 42% respondents ranked for insects as a main problem followed by 32% for weed and 17% for disease (fig 1). Among the insects, stem borer was major threat of maize in the field condition. Insect pests and diseases have been playing a significant role in reducing production and productivity of maize (Shivakoti and Manandhar 2000). They also reported that these organisms are responsible for decline in quantity, quality and germination potential of maize seeds in storage. Stem borer only causes 27-85% damage (Dhaliwal and Arora, 2001). The annual yield loss in maize because of weed problems was estimated to be approximately 10 % (Plessis, 2003).



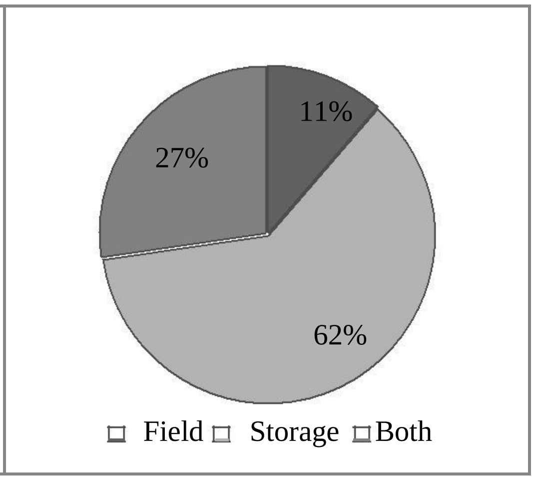


Fig 1:Major problem of maize production in the hil **Fig 2: Grain losses at field and storage condition**

At post harvest, 62% respondents were expressed their view on insects as a main problem in storage whereas field condition constraints indicated only by 11% respondents (fig 2). Maize was attacked by a wide range of insect pests both in the field and in the storage (Neupane *et al.*, 1991).

2. Storage insect-pests and farmer's perception

Farmers in survey area reported that weevil appeared just after harvesting in some cobs that is the source of infestation and it was found in increasing trend in recent years. Nearly all of the important insect pests of stored products are either beetles or moths. Both rodent and insect pests were more or less equally threat in storage in survey area (fig 3). The losses caused by diseases were negligible in survey area and very few farmers pointed out the problem of disease during storage. K.C. (1987) reported that maize grain loss due to rodents, insects, and mold to be 4.6, 3.1 and 0.2% respectively. Maize weevils alone cause up to 32% losses in storage (Panthee *et al.*,1993), 20-25% due to insects, rodents, mites and others, 15-20% losses reported by KC (1992).

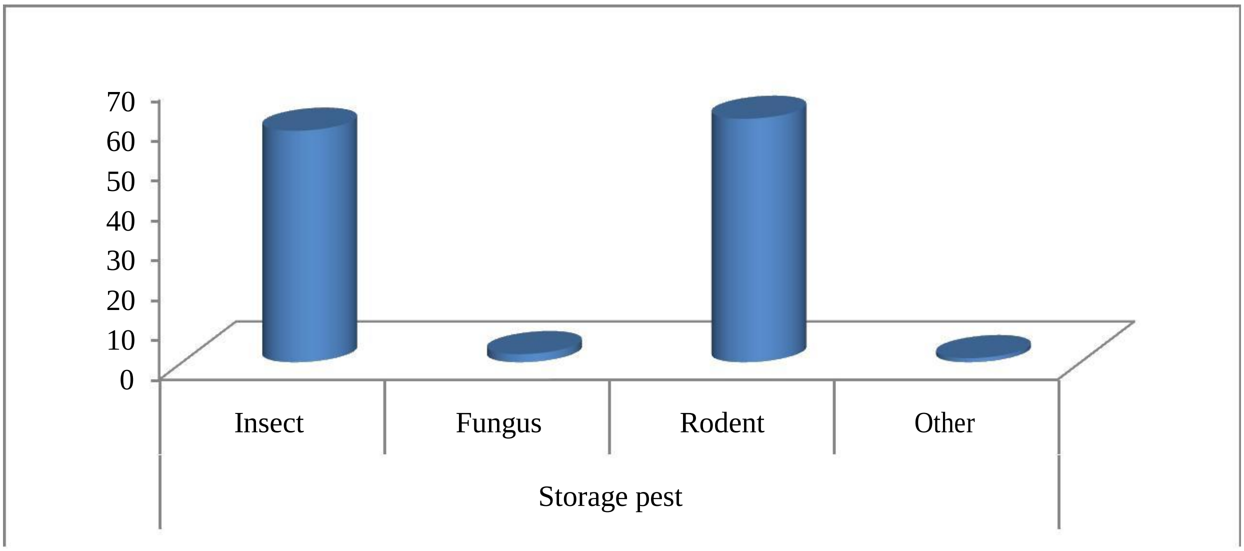
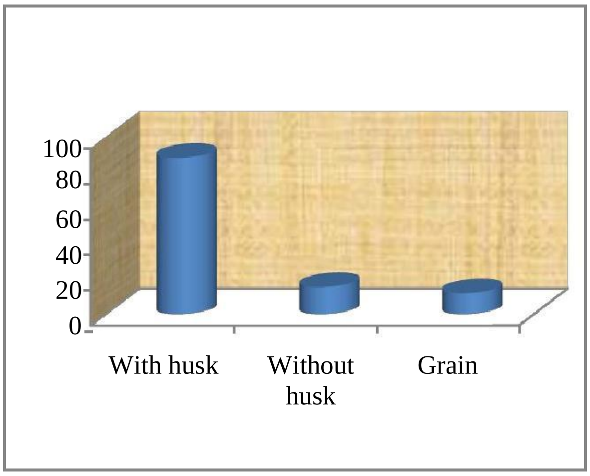


Fig 3:Major insect/pests in maize storage

3. On farm maize storage system

Nearly 40% respondents were using open floor in upper stair "*Aati"*as a major maize storage place in Palpa, Gulmi and Syangja, whereas (79%) were using sack to store shelled grains in Baglung (fig 4). Maize cobs stored in the local storage structures such as open storage, semi open storage or closed storage were found to be heavily infested by insect pests in the mid and high hills of Nepal. But in mid hills of Nepal, maize cobs are stored on Thankro/Suli, hanging on ropes, Kuniu and sundried mud structures (Dehari) (Manandhar and Shrestha, 2000). Nearly 80% farmers in Tanahun stored maize in "Kuniyu" a semi-open maize storage system (G.C., 2001). Metal bin was found superior in terms of its ability to give 91% germination within six months of storage followed by jute bag (88 %) and bamboo mat (73.50%) respectively (G.C., 2006).



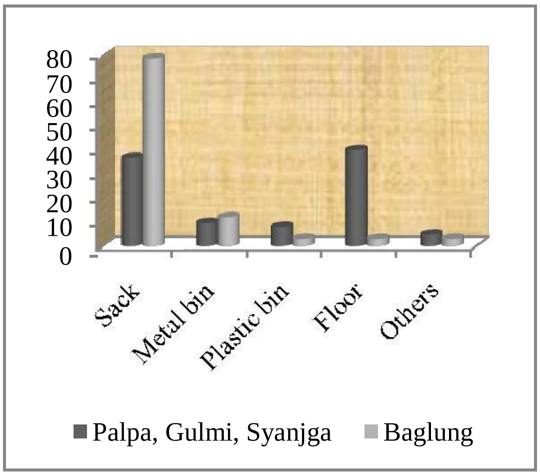
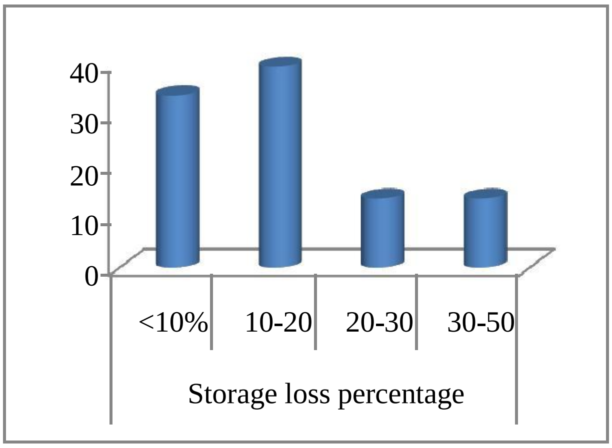


Fig 4:Maize storage methods in mid hills of Nepal **Fig 5: Maize storage devices used in surveyed areas**

4. On farm losses of maize

The survey revealed that majority of respondents (39%) found 10-20% losses during storage (fig 6). Similarly, G.C. (2001) reported that 30-35% loss the grain especially in those ear which are stored in Kuniyu. 15-20% (K.C, 1992), 32% (Paneru *et.al.*, 1993), 40-50% (Manandhar, *et al.*, 2001) and Manandhar and Mainali (2000) reported (7.44%) losses in maize storage. Post harvest loss may occur during harvesting, transportation, drying, threshing, processing and storage. However, losses during storage have been widely recognized (G.C., 2000).



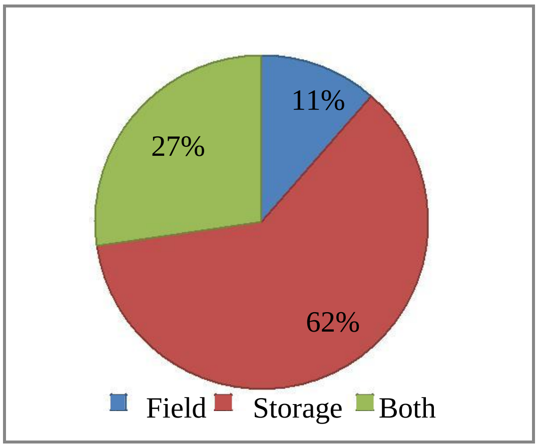


Fig 6:Maize grain storage losses in surveyed area conditions **Fig 7: Losses of maize in field and storage**

5. Awareness of moisture percentage of grain during storage

In survey areas, only 40 percent respondents were aware of the role of moisture content in grain for the storability (fig 8). Similarly, 92% of the respondents expressed that emergence of insect occurred within 4 months after storage of maize grains (fig 9). In addition to seed moisture, storage temperature and relative humidity were considered highly important in safe storage of maize seeds. The rate of growth of stored pests, chemical and physical changes increased greatly by the moisture content as well as with ambient temperature. It is reported that the moisture content and temperature of the stored grain if go higher than 13% and 70^{0}F (21^{0}C), respectively,

grain in storage starts deteriorating rapidly. Harrinton, (1972) reported that for each 1% moisture in seed moisture content or $5^{0}C$ reduction in storage temperature, there is a doubling of storage life. So, the role of moisture percent is very important for the management of storage pests. Farmers do not follow preventive measures such as reduction of the moisture level by drying (G.C., 2001).

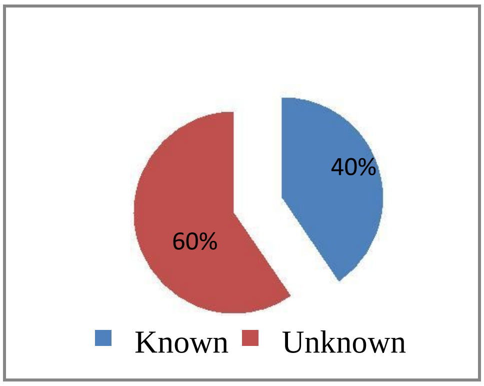


Fig 8:Farmer's perception on moisture percentage

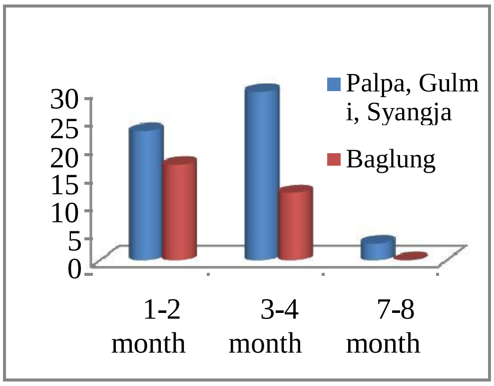


Fig 9:Emergence period of insect pests in maize storage

6. Pest management system at farmer level

Majority of the households in Palpa, Gulmi and Syangja did not use chemical pesticides and improved seed bins as compare to Baglung district. Celphos (zinc phosphide) was used by 30% respondents, 11% used improved seed bin whereas 23% used botanicals against storage pests. Pest management is a decision-making process that leads to pests being controlled in a cost effective manner. Sun drying was only the way of pest management practices in these region. Among the bio-rational plants product, Sweet flag stolen *(Acorus calamus*), Neem oil, *(Azadirachta indica*), Neem seed powder, Timur (*Zanthoxylum armatum)*, Titepati *(Artimesia vulgaris)* have been reported to be superior in controlling the maize weevils (Paneru *et al.*, 1996). In suli, 10% farmers use some barriers such as leaf of pine, dalle kuro, babio, red and white soil to prevent the rat invasion.

CONCLUSION AND RECOMMENDATION

On the basis of the survey result, insect pests were major problems during storage than field condition in the surveyed areas. The main causes of post-harvest losses in survey areas was traditional methods of storage. Most of the farmers stored maize cobs with husk in upper stair "Aati" for 5-7 month in Palpa, Gulmi and Syangja district but sacks and metal bins in Baglung district to store the shelled grain. Less than half of the respondents were aware of moisture content and its role on seed storability. Maize grain or seed loss in storage range were 10-20%. Sun drying was the pest management practices and very few farmers used chemicals insecticide and botanicals against storage pests. Important causes for low adoption of recommended post-harvest technologies were economical and social. Therefore, need to be design and development of appropriate post harvest loss reduction technology for the hills farmers. There is an ample opportunity to reduce the storage losses of maize by improving the farmer's storage systems and through the adoption of preventive measures as an integrated package.

ACKNOWLEDGEMENTS

The authors are highly indebted to NARC and NMRP for their technical and financial support. Technical staffs of NMRP and collaborating farmers of Western hills are also highly acknowledged.

REFERENCES

Aulakh, J., & Regmi, A. (2013). Post-harvest food losses estimation- development of consistent methodology. Available at: /http:// www.fao.org.

Bajracharya, A.S.R., Timilsina, Y.P., & Paneru, R.B. (2007). Minimizing losses caused by *Sitophilus oryzae* Linn. in stored maize under farmers' storage conditions (*kunio and thangro*) with Bojo (Sweet flag) in the hills of Nepal. Proceedings of the 25th National Summer Crops Research Workshop, pp281-288.

Boxal, R. A., & Gillet, R. (1980). Farm level storage losses in eastern Nepal. Tropical Product Center, Slough, U.K.

Boxall, R.A., & Gillet, R. (1984). Farm level storage losses in eastern Nepal. *Trop. Stored Prod. Inf.*, 50, 20-25.

Dhaliwal, G.S., & Arrora, R. (2001). Integrated pest management concept and approach, Kalyani publisher, New Delhi.

GC, Y. (2006). Efficacy of Indigenous Plant Materials and Modified Storage Structures to Insect Pests of Maize Seed During On-Farm Storage. *J. Inst. Agric. Anim. Sci.*, 27, 69-76.

GC, Y. (2001). Study on post harvest losses of maize and their management practices in the Western hills of Nepal. A survey report, Trivhuwan University, Institute of Agricultural and Animal Science Rampur, Chitwan and CIMMYT-Nepal, Kathmandu.

Ghimire, A.J, Khanal, R. and Katuwal, K. (1996). Post-harvest storage situation in the eastern hills and losses in grain quantity and quality of field crops of Nepal, PAC working paper, Pakhribas Agricultural Center, Dhankuta, Nepal.

Golob, P. (1994). On farm storage in the hill areas of Nepal: the potential for using plants as protectants of stored grain. Visit report, 24 April to 6 May, 1994. NRI. Overseas Development Administration, UK.

Gyawali, B.K. (1993). Integrated pest management through indigenous techniques in Nepal. In Tamang et.al. (eds.) Indigenous management of national resource in Nepal. HMGN/MOA. Winrock International, Kathmandu, Nepal.

Harrington, J.F. (1972). Seed storage and longevity . In Seed Biology Eds. T.T. Kozlowski, 3:Pp. 145-245. Academic Press, New York and London.

KC, G. (1992). On farm level pre-harvest and post-harvest food loss preventive system in Nepal. Proceeding of National Seminar on Issues & Constraints Related to Post Harvest Food Loss Management 27-29 April. 1992, Kathmandu.

KC, G. (1997). A Review of the Post Harvest System in Nepal. *Nepalese Journal of Agriculture*, 18, 113-122.

Khanal , R., Dawadi, Y.R., Neupane, P.R., & Ghimire, A.J. (1990). A report on the effect of local available plant materials against *Sitophilus oryzae* in maize. Paper presented at the Summer Crop Seed Workshop held at PAC, Dhankuta, Nepal.

Manandhar, G.B., & Shrestha, K. B. (2000). Drying and Storage Structures to Minimize Maize Post-harvest Losses in Nepal: Developing and disseminating technology to reduce post harvest losses in maize-Proceeding of a working group meeting of the Hill Maize Research Project. Kathmandu: NACR and CIMMYT.

Manandhar, D.N., Ransom, J.K., & Rajbhandari, N. P. (2001). Developing and Disseminating Technology to Reduce Post-harvest Losses in Maize -Proceedings of a Working Group Meeting of the Hill Maize Research Project. Kathmandu: NARC and CIMMYT.

Manandhar, D.N., & Mainali, B.P. (2000). Review of research on post harvest insect control in Nepal: Developing and disseminating technology to reduce post harvest losses in maize-Proceeding of a working group meeting of the Hill Maize Research Project. Kathmandu: NACR and CIMMYT.

Manandhar, G., & Batsa, B.K. (2000). Review of research in Nepal on Disease-related Post-harvest Losses in Maize: Developing and disseminating technology to reduce post harvest losses in maize-Proceeding of a working group meeting of the Hill Maize Research Project. Kathmandu: NACR and CIMMYT.

Mettananda, K.A., Weerasena, S.L., & Liyanage, Y. (2001). Effect of storage environment, packing material and seed moisture content on storability of Maize (Zea mays L.) seeds. *Annals of the Sri Lanka Department of Agriculture,* 3,131-142.

Neupane, F.P., Shrestha, S. M., Thapa, R.B., & Adhikari, T.B. (1991). Crop protection (Nepali). Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal.

Paneru, R.B., Duwadi, V.R., Khanal, R., & Bhandari, M.R. (1996). Testing of the efficacy of some materials against weevil in stored maize. PAC working paper no.139, Dhankuta, Nepal.

Paneru, R.B., Duwadi, V.R., Khanal, R., & Bhattarai, M.R. (1993). Testing of locally available plant materials against weevil in stored maize grains. PAC, Dhankuta, Nepal.

Panthee, D.R., Duwadi, V.R., Rana, L.K., Adhikari, R.B., & Devkota, H.P. (1993). Seed storage research at LARC. Working paper No. 1993/04.

Plessis, J. (2003). Maize production. DEPARTMENT: AGRICULTURE REPUBLIC OF SOUTH AFRICA. Available on the web: www.nda.agric.za/publications

Pradhan, R.B., & Manandhar, K.L. (1992). Post harvest technology generation and transfer for food losses management. Proceeding of National Seminar on losses and constraints related to post harvest loss management, 27-29, APL, 1992.

Sah, Y. P. (1999). Minimizing the losses in stored maize under farmer's storage conditions in the eastern hills of Nepal. ARSP Technical Paper No. 188, PAC, Dhankuta, Nepal.

Sherpa, L., Ojha, N.G., & Sharma, A.R. (1997). Why farmers adopt or reject Agricultural Technology: A case study of improved maize and wheat varieties in the Ex- local largest area of Pakhribas Ag. Center at Dhankuta. PAC Technical paper no 177.

Shivakoti, G.P. (1984). Post harvest losses at storage due to stored grain pests of maize under different storage structures. The Eleventh Summer Crops Workshop held at Parwanipur Agriculture station, Parwanipur, Jan 30- Feb. 2 1984, pp. 28-39.

Shivakoti, G.P., & Manandhar, D.N. (2000). An Overview of Post-harvest Losses in Maize in Nepal: Developing and disseminating technology to reduce post harvest losses in maize-Proceeding of a working group meeting of the Hill Maize Research Project. Kathmandu: NACR and CIMMYT.

Upadhyay, S.R., Sharma, D., Mahato, R.K., Paudel, D.C., Koirala, K.B., Parsad, R.C., Shah, S.N., Katuwal, R.B., Pokhrel, B.B., Dhakal, R., & Dhami, N.B. (2007). Development of QPM (Quality Protein Maize) Varieties for the Hills of Nepal. Proceedings of the 25th National Summer Crops Research Workshop, National Maize Research Program, Nepal Agricultural Research Council, Kathmandu, Nepal. pp.31-38

Journal of Maize Research and Development (2015) 1(1):106-111

ISSN: 2467-9305 (Online)/ 2467-9291 (Print)
DOI: 10.5281/zenodo.34291

Performance evaluation of early maize genotypes in far western hills of Nepal

Hari Kumar Prasai[1*], Ujjawal Kumar Singh Kushwaha[1], Bishnu Prasad Joshi[1] and Jiban Shrestha[2]

ARTICLE INFO

Article history:
Received:
12th September, 2015 Revised:
7th October, 2015 Accepted:
9th November, 2015

Keywords:
Performance,
evaluation,
maize, genotypes

ABSTRACT

Initial evaluation trial of maize (early) genotypes was carried out at Regional Agricultural Research Station, Doti, Nepal in 2013 and 2014. Total fourteen and fifteen genotypes of early maize were included in initial evaluation experiment of the year 2013 and 2014 respectively. The experiment was laid out in randomized complete block design (RCBD) with three replications in each year. Out of the tested genotypes, SO3TEY/LN, ZM 423 and SO3TEY-FM (ER) identified as promising from statistical analysis over year. All the tested characters were found statistically significant. Similarly, the coordinated varietal trial of maize (early) was also carried out in the same station at 2013 and 2014. Total fourteen genotypes in 2013 and fifteen genotypes in 2015 of maize (early) were included in the experiment. The RCB design was applied and the experiment was replicated three times in every year. ZM 627 and ZM 621/Pool -15 genotypes identified as superior next to Arun-2 from the analysis of two year data. All the tested traits were found statistically significant in over year analysis.

INTRODUCTION

Maize (*Zea mays* L.) occupies second largest cultivated area (849635 ha) after rice (1420570 ha) in the country. Out of the total cultivated area of cereal crops (3339077 ha), the share of maize cultivation is 25.44%. The contribution of agriculture and forestry sector in GDP is 34.74% and 65.6% population are being engaging in agriculture sectors. National average productivity of maize is 2353 kg/ha (MoAD, 2013). Amongst the total cereal production of the country (8580285 mt), the contribution of maize is 23.29%. The status of maize cultivation and production in far western development is different. Maize is being cultivating in 45846 ha and it falls under third crop after rice (160701 ha) and wheat (140844 ha) in far western development region of the country. The average productivity of maize in this development region is 1831 kg/ha which is 22.18% low compared to the national average productivity. The contribution of maize in total cereal productionis about 10% and it occupies 12 % cultivated area of the total cereal cultivated area of far western development region (MoAD, 2013). Maize cultivation is a way of life for most farmers in the hills of Nepal (Adhikari, 2000).

Corresponding author Info:
*1Regional Agricultural Research Station, Bhagetada, Doti, Nepal 2National Maize Research Program, Rampur, Chitwan, Nepal *E-mail: hkprasai60@gmail.com*

It is traditional crop cultivated as food, feed and fodder on slopping Bari land (rainfed upland) in the hills. It is grown under rainfed condition during the summer (April-August) as a single crop or relayed with millet in the later season. In the terai, inner terai, valleys and low-lying river basin areas, maize is also grown in the winter and spring with irrigation (Paudel *et al*., 2001). Maize is cultivated in a very diverse environment in Nepal (NPC, 1994). Maize has feature that has contributed to its broad morphological variability and geographical adaptability. Maize can be classified based on environment in which it is grown, maturity class and use (Yanli Lu et al, 2009). Maize exhibits extensive genetic variation (Buckler and Stevens, 2005).Besides other factors, biotic and abiotic stresses are supporting to limit the maize yield in many developing countries (Prasana, 2012). Production may not be able to meet the demand without technological and policy interventions (Shifegrowth *et al.*, 2011). Another important challenge that threatens the long term production growth of maize is the changing global climate (Cairns *et al.*, 2012).Far western development region is the drought prone region of the country. Farmers of far western hills prefer early maturing varieties suitable to their existing cropping system. Unavailability of high yielding genotypes of maize suitable to agro-climatic condition of far western development region is one of the reasons of low productivity of maize in this region. So this research was carried out to identify the high yielding and early maturing genotypes of early maize.

Description of the experimental site

Regional Agricultural Research Station, Bhagetada, Dipayal, Doti is located in far western development region of the country. This research station is situated at an altitude of 610 meter above sea level with $29^{0}15'$ north latitude and $80^{0}55'$ east longitude. This research station represents for river basin agro-environment of far western hills and generally annual rainfall is less than 1000 mm, but year round irrigation facility is available (Anonymous, 2012).

MATERIALS AND METHODS

The RCB design was applied in seeding initial evaluation trial (IET) of maize (early) in both year (2013 & 2014). This experiment was replicated three times in each year. Total fourteen and fifteen genotypes of maize (early) were included in initial evaluation experiment of 2013 and 2014 respectively. The gross plot size was maintained by 6 m^2 and harvested plot size was also same. The experiments of both years were seeded at the spacing of 75 cm row to row and 25 cm plant to plant. Those genotypes which were similar in initial evaluation experiment of both year (2013 and 2014) were included in analysis over year. Only ten genotypes were included in combined analysis over year, they are: SO3TEY-FM(ER), SO3TEY-SEQ, Across-2401, SO3TEY/LN, ACO-2401/ACO-2402, Rampur SO3EO2, Arun-1, EEYC1, ZM 621/Pool-15 and ZM 423.The coordinated varietal trail of maize (early) was carried out in 2013 and 2014 at RARS, Doti. The experiment was laid out in RCB design in both years. The experiment was replicated three times in every year. The gross plot size was maintained by 12 m^2 and net harvested plot size was of 6m^2 in both years. The experiments of both years were seeded in 75 cm row to row spacing and 25 cm plant to plant spacing. The genotypes included in the experiment of 2013 were: POP 445, POP 446, S97TLYGH “AyB” (3), POP 445/POP 446, POP 45/Pool17, Rampur composite/Pool-17, POP 44/Pool 15, Arun-2, Farmers’ variety, ZM 627, ZM 621/Pool-15, EEYC1, ZM 423 and Pool-27. Similarly, the genotypes included in coordinated varietal experiment of 2014 were: Across 2401, Rajhar Local, S97TLYGH”AyB’ (3), POP 445/POP 446, Arun-1EV, Rampur composite/Pool-17,

SO3TEY/LN, Arun-2, Farmers' variety, ZM 627, ZM 621/Pool-15, EEYC1, Khumal yellow/Pool-17, Pool-27 and Pool-15. Total nine genotypes which were included in both years' experiment were incorporated in over year analysis, they are: S97TLYGH"AyB" (3), POP 445/POP 446, Rampur composite/Pool-17, Arun-2, Farmers' variety, ZM 627, ZM 621/Pool 15, EECY1 and Pool-23. The CVT and IET sets were obtained from National Maize Research Program, Rampur, Chitwan, Nepal. The fertilizer was applied at the rate of 120:60:40 NPK kg/ha in both IET and CVT. Half dose of nitrogenous fertilizer and full dose of phosphorus and potash was applied as basal dose and remaining half dose of nitrogenous fertilizer was applied in two split doses, that is, after first and second hoeing. The seed sowing was done at the rate of 20 kg/ha and both experiments were carried out in summer season. Irrigation was supplied as per the need of the crop. Furadon was applied at the rate of 20 kg/ha to control stem borer. Data of days to tasseling, days to silking, plant height, ear height and grain yield were recorded and analyzed by using Excel and MSTATC software.

RESULTS AND DISCUSSION

Out of the genotypes included in the coordinated varietal experiment of 2013, the longest anthesissilking interval (ASI) was observed in ZM 423 (4.33 days) whereas the shortest ASI was found in ZM 627 (1.66 days). POP 45/Pool 17 genotype was found tallest in plant height (262.67 cm) and ear height (119.33 cm) whereas S97TLYGH"AyB"(3) (198.33 cm) and POP 445/POP 446 (199 cm) identified as dwarf genotypes of maize (early). Although standard check variety, Arun-2, recorded the highest grain yield (4067.83 kg/ha), POP 445 (3876.77 kg/ha) and EEYC1 (3847.87 kg/ha) identified as superior genotypes of maize (early) in the CVT experiment of 2013 (Table 1). Statistically, all the traits tested in the experiment were found significantly different due to genotypes.

Table 1. Performance of maize (early) genotypes in coordinated varietal trial at RARS, Doti during 2013.

SN	Genotype	Day to tasseling	Day to silking	Plant height (cm)	Ear height (cm)	Grain yield (kg/ha)
1	POP 445	42.33	45.67	233.00	76.67	3876.77
2	POP 446	43.00	45.33	227.00	81.00	3742.80
3	S97TLYGH"AyB" (3)	41.00	44.00	198.33	71.67	2914.63
4	POP 445/POP 446	40.67	44.33	199.00	69.33	2740.47
5	POP 45/Pool 17	43.00	45.67	262.67	119.33	3029.50
6	Rampur Composite/Pool -17	43.33	45.67	231.33	104.33	3331.50
7	POP 44/Pool-15	46.33	48.67	242.00	97.00	3435.67
8	Arun-2	43.67	46.33	245.67	105.67	4067.83
9	Farmers' Variety	31.67	34.67	226.00	72.69	2023.01
10	ZM 627	52.67	54.33	235.67	99.00	2978.22
11	ZM 621/Pool 15	44.33	46.46	215.67	85.00	3692.17
12	EEYC1	44.00	47.00	239.00	93.67	3847.87
13	ZM 623	52.00	56.33	259.00	104.33	3504.43
14	Pool 27	41.33	45.33	235.67	104.00	3345.70
	F-test	**	**	**	**	**
	CV %	3.79	2.98	6.70	9.24	15.52
	$LSD_{0.05}$	2.77	2.32	26.11	14.23	862.37

National Maize Research Program, Rampur, Chitwan, Nepal had discarded some genotypes from CVT set of 2013 and had included some new genotypes in CVT sets of 2014. Amongst the tested genotypes, the shortest ASI (2 days) was found in POP 445/POP 446 while the longest ASI (3.67 days) was found in ZM 621/Pool 15 and Arun 1 EV. The highest plant height (264.33 cm) was observed in Pool 15 whereas Across 2401 recorded the lowest plant height (197.33 cm). Out of the genotypes included in the experiment of 2014, SO3TEY/LN produced the highest grain yield (5292 kg/ha). ZM 627 identified as superior genotype by producing 4709.67 kg/ha grain yield, though the grain yield was 4.56% low compared to the grain yield of standard check variety, Arun-2 (4934 kg/ha). Statistically, all the tested characters were found significantly different due to genotypes (Table 2).

Table 2. Performance of maize (early) genotypes in coordinated varietal trial at RARS, Doti during 2014.

SN	Genotype	Day to tasseling	Day to silking	Plant height (cm)	Ear height (cm)	Grain yield (kg/ha)
1	Across-2401	54.67	57.33	197.33	72.00	1446.33
2	Rajhar Local	53.67	56.67	272.33	136.33	3358.00
3	S97TLYGH"AyB"(3)	46.00	48.67	228.00	96.00	4024.00
4	POP 445/POP 446	45.67	47.67	225.67	103.00	4029.00
5	Arun 1 EV	48.00	51.67	248.00	122.67	3693.33
6	Rampur Composite/Pool 17	51.67	53.67	243.00	112.33	2710.67
7	SO3TEY/LN	52.67	54.67	243.33	123.33	5292.00
8	Arun-2	49.67	52.00	256.00	120.33	4934.67
9	Farmers' variety	44.00	46.33	235.67	103.00	3171.67
10	ZM 627	56.00	59.00	246.67	108.67	4709.67
11	ZM 621/Pool-15	50.33	54.00	240.67	102.67	3844.33
12	EEYC1	50.00	52.67	238.67	106.00	3868.67
13	Khumal Yellow/Pool-17	50.00	52.67	259.33	113.33	4076.33
14	Pool-27	49.67	52.33	245.67	111.33	3802.00
15	Pool-15	49.00	52.00	264.33	131.00	4142.33
	F-test	**	**	**	**	**
	CV %	3.23	2.77	6.80	10.71	13.96
	$LSD_{0.05}$	2.71	2.43	27.65	9.84	888.79

Analysis over year was done of those genotypes which were included in the experiment of 2013 and 2014. The shortest ASI (2.17 days) was found in S97TLYGH "AyB' (3) and Rampur composite/Pool-17 whereas ZM 621/Pool-15 showed the longest ASI (3 days). The highest plant height (250.83 cm) and ear height 113 cm) was observed in standard check variety, Arun-2. Although, Arun-2 produced the highest grain yield (4501 kg/ha), ZM 627 and ZM 621/Pool-15 identified as superior genotypes with the grain yield production of 3753 kg/ha and 3778 kg/ha (table-3). All the tested characters were found significantly different due to genotypes and genotype by year in over year analysis.

Out of the fourteen and fifteen genotypes of maize (early) included in IET experiment of 2013 and 2014, only those genotypes which were incorporated in IYT experiment of both years were taken for over year analysis. Only the over year analysis of two year data of IET has been presented in this paper. The shortest days to tasseling (46.67) and silking (49.67) was observed in EEYC1 whereas the longest days to tasseling (51.83) and silking (54.83) was found in ZM 423. The highest plant height (268.17 cm) and ear height (130.17 cm) was observed in standard check variety, Arun-1. SO3TEY/LN produced the highest grain yield (5572.33 kg/ha) followed by ZM 423 (5268.33 kg/ha) and SO3TEY-FM (ER) (4922 kg/ha)

in the analysis of two year experimental data. Statistically, all the tested characters were found significantly different in over year analysis (Table 4). Pokhrel *et al.* (2014) also agreed with SO3TEY-FM (ER) as the promising genotype of early maize for river basin areas of mid-western hills of Nepal.

Table 3. Grain yield and other ancillary characters of maize (early) in over year analysis (2013 and 2014) of coordinated varietal trial at RARS, Doti

SN	Genotype	Day to tasseling	Day to silking	Plant height (cm)	Ear height (cm)	Grain yield (kg/ha)
1	S97TLYGH"AyB"(3)	43.50	45.67	213.17	83.83	3469.00
2	POP 445/POP 446	43.17	46.00	214.00	86.17	3368.17
3	Rampur Composite/Pool-17	47.50	49.67	237.17	108.33	3019.17
4	Arun-2	46.67	49.17	250.83	113.00	4501.00
5	Farmers' variety	36.33	39.17	230.83	87.83	2430.50
6	ZM 627	54.33	57.17	241.17	103.83	3753.67
7	ZM 621/Pool-15	47.33	50.33	228.17	93.83	3778.00
8	EECY1	47.00	49.67	238.83	99.83	3287.00
9	Pool-27	45.50	48.83	240.67	107.67	3423.67
	Genotype (G)	**	**	**	**	**
	Year (Y)	**	**	**	**	**
	G × Y	*	**	NS	NS	**
	CV%	3.19	2.80	6.29	9.73	8.24

Table 4: Grain yield and other ancillary characters of maize (early) in over year analysis (2013 and 2014) of initial evaluation trial at RARS, Doti

SN	Genotype	Day to tasseling	Days to silking	Plant height (cm)	Ear height (cm)	Grain yield (kg/ha)
1	SO3TEY-FM(ER)	48.33	50.83	240.67	110.33	4922.00
2	SO3TEY-SEQ	47.83	50.67	234.50	97.17	4473.00
3	Across-2401	49.67	52.83	224.33	88.33	3260.33
4	SO3TEY/LN	50.00	52.83	254.00	117.00	5572.33
5	ACO-2401/ACO-2402	50.00	52.83	232.67	104.50	4784.50
6	Rampur SO3EO2	50.33	53.50	219.50	99.33	3385.50
7	Arun-1	47.83	50.67	268.17	130.17	3741.50
8	EEYC1	46.67	49.67	229.67	103.17	3888.33
9	ZM 621/Pool-15	47.00	52.00	220.83	92.00	3097.33
10	ZM 423	51.83	54.83	247.50	112.67	5268.33
	Genotype (G)	**	**	**	**	**
	Year (Y)	**	**	NS	NS	NS
	G × Y	NS	NS	NS	NS	**
	CV%	4.00	3.15	10.64	13.45	29.25

CONCLUSION

In CVT, although ZM 623 and ZM 621/Pool-15 were foundnext to standard check in grain yield production, they are emerging as superior genotypes for far western hills and are recommended to continue this experiment one year more to verify the stability of the experimental results. In IET, SO3TEY/LN, ZM 423, SO3TEY-FM (ER), ACO-2401/ACO-2402 and SO3TEY-SEQ genotypes were found promising for far western hills and is recommended to include in CVT for further varietal improvement program.

ACKNOWLEDGEMENTS

Authors are grateful to the Executive Director, Director of Crops and Horticulture Research, Nepal Agricultural Research Council and National Coordinator and Scientists of National Maize Research Program, Rampur, Chitwan, Nepal for their financial and technical support in conducting these experiments at RARS, Doti.

REFERENCES

Adhikari, K. (2000). Maize Research Strategy in Nepal. In: Adhikari K. and B. Batsa (eds). Proceedings of 22nd National Summer Crops Workshop, Rampur, Chitwan, Nepal.National Maize Research Program.Pp 25-36.

Pokhrel, A., Pokhrel, K.R., Pun, G.M., Chhetri, N.S., Dhakal, J.P., Ghimire, T.B., & Kunwar, C.B. (2014). Varietal investigation on open pollinated early maize for the river basin areas of mid western hills of Nepal. In: Proceedings of the 27th National Summer Crops Workshop. Vol-1.Pp 164-168.

Anonymous, (2012). Annual Report. Regional Agricultural Research Station, Bhagetada, Dipayal, Doti

Buckler, E.S.,& Steven, N.M. (2005).Maize Origin, Domestication and Selection. In: Motley TJ, Zerega N. Cross H (eds) Darwin's Harvest. Columbia University Press New York.Pp 67-90.

Cairns, J.E., Sonder, K., Zaidi, P.H., Verhulst, N., Mahuku, G., Babu, R., Nair, S.K., & Das, B. (2012). Maize production in a changing climate: impacts, adaption and mitigation strategies. *Advance Agronomy,* 114, 1-58.

MoAD, (2013).Ministry of Agricultural Development. Agribusiness Promotion and Statistics Division, Singh Durbar, Kathmandu, Nepal

National Planning Commission (1994). Agricultural Statistics of Nepal : Revised Cropped Area Series (1974/75 – 1991/92), Kathmandu, Nepal.

Paudel, K., Joel, R., Ranson, K., Rajbhandari, N.P., Adhikari, K., Gerpacio, R.V., & Pingali, P.L. (2001). Maize in Nepal: Production Systems, Constraints and Priorities for research, Kathmandu, NARC and CIMMYT.

Prasanna, B.M. (2012). Diversity in maize germplasm: Characterization and Utilization. *Journal of Bioscience*, 37(5), 843-855.

Shiferaw, B., Prasanna, B., Hellin, J., & Benziger, M. (2011).Crops that feed the world. Past success and future challenges to the role played by maize in global food security. *Food Security* ,3, 307-327.

Yanli, L., Jianbing, Y., Claudic, T., Guimaras, S.T., Zhuanfang, H., Shibin, G., Shaojing, C., Jiansheng, Li., Shihung, Z., Bindiganavile, S.V., Cosmos, M., Stephen, M., Dan, M., Sidney, N., Parentoni, T.S., Tnigzhao, R., Jonathan, H., Crouch, Y.X. (2009). Molecular characterization of global maize breeding germplasm based on genome-wide single nucleotide polymorphism. *Theo. Appl. Genet*, 120, 93-115.

Journal of Maize Research and Development (2015) 1(1):112-122

ISSN: 2467-9305 (Online)/ 2467-9291 (Print)
DOI: 10.5281/zenodo.34290

Productivity and profitability of maize-pumpkin mix cropping in Chitwan, Nepal

Shiva Chandra Dhakal[1*], Punya Prasad Regmi[2], Resham Bahadur Thapa[3], Shrawan Kumar Sah[4] and Dilli Bahadur Khatri-Chhetri[5]

ARTICLE INFO

Article history:
Received:
7th September, 2015
Revised :
11th October, 2015
Accepted:
15th November, 2015

Keywords:
Productivity, profitability, returns to scale, Allocative efficiency, Cobb-Douglas production function, pollinators

ABSTRACT

The study was conducted to determine the productivity, profitability and resource use efficiency of maize-pumpkin mix crop production in Chitwan. The study used 53 maize-pumpkin mix crop adopting farmers from among 300 farmers adopting different pollinator friendly practices. Descriptive and statistical tools including Cobb-Douglas production function were used to analyze data, collected from structured interview schedule. The benefit cost ratio (1.58) indicates that maize-pumpkin mix cropping was profitable with productivity of 2.83 ton per ha on maize main product equivalent basis. The magnitude of regression coefficients of maize-pumpkin mix cropping implied that expenditure on seed and fertilizer and irrigation had significant positive effect on gross return with estimated decreasing return to scale (0.85). According to estimated allocative efficiency indices, it is suggested to increase expenditure on seed and fertilizer cum irrigation by about 90% and 55% respectively. Extension of modern technologies with adjustment on resource use is to be encouraged for increase in productivity and profitability of maize-pumpkin mix crop production which indirectly promotes and ensure forage for pollinators

INTRODUCTION

Maize (*Zea mays* L.) is second most important cereal crop of Nepal and is popularly known as *Makai* in Nepal. It occupied 8,49,635 ha of land area, with the production of 19,99,010 t and productivity of 2.35 t/ha (MoAD, 2013). This crop is cultivated mainly for food, feed and fodder purpose on both irrigated as well as non-irrigated land across the different agroclimatic condition of the country (Paudyal & Poudel, 2001). Specifically, it is subsistence staple food crop in hill area of the country and mostly used as feed in terai and inner terai of the country which is growing it as important cash crop in the area. It is general practice of growing pumpkin (*Cucurbita moschata*) as mix crop with maize in Nepal as important vegetable component in summer and rainy season. This type of mix-cropping system makes the cropping system pollinator friendly as compared to mono-cropping of maize. It is imperative to recognize the factors that hinder farmer's resource use efficiency in

Corresponding author Info:
1Asst. professor, AFU, Rampur, Chitwan, Nepal
2Professor (Agricultural Economics), TU, IAAS, Rampur, Chitwan, Nepal
3Professor (Entomology), TU, IAAS, Rampur, Chitwan, Nepal
4Professor (Agronomy), AFU, Rampur, Chitwan, Nepal
*5 Seed Value Chain and Marketing Expert at CIMMYT International, Nepal *Email: nepal_dhakal@ymail.com*

maize-pumpkin mix cropping production and further quantify the extent to which the resources are to be adjusted for optimum economic advantage. Area under maize in Chitwan in 2013 was 29400 ha and productivity was 3.4 t/ha (DADO, 2014). Honeybees and other natural pollinators visit on very attractive flowers of pumpkin and ultimately results into cross pollination. If maize only is grown in monocropping system, then it avoids visit of honey bees. Growing pumpkin mixed with maize provides foraging space for bees which is not possible in monocrop of maize. Honeybees are natural pollinators of plants throughout their natural range. The main significance of honey bee keeping is pollination with honey and wax as products of secondary value (Verma, 1990). Pollination is a critical link in the functioning of ecosystems and it is essential for the production of a wide range of crops. Several studies have shown that pollination makes a very significant contribution to the agricultural production of a broad range of crops, in particulars fruits, vegetables, fiber crops and nuts (Gordon & Davis, 2003). Crop pollination services are being hampered by a decline in the number and diversity of pollinator populations throughout the Hindu Kush Himalayan region (Partap *et al*., 2001). Pollinator loss in Chitwan has been attributed to habitat loss resulting from misuse of fertilizers and pesticides, reluctant in beekeeping, deforestation, loss of natural vegetation, increased commercial agriculture, use of high yielding varieties, monocropping and; many other abiotic and biotic factors (Devkota, 2013). Pollinator friendly practices are those which increase forage for pollinators through mixed crop types over a growing season, planting crop with long flowering period, growing crop with mass flowering, mixed crop types with at least one pollinator attractant crop, greater crop genetic diversity, patches of non crop vegetation, shade tree cultivation, strip cropping, conservation of grass lands etc. Secondly, practices for reducing use of chemicals like selective weeding to conserve weed for pollinators, organic farming, use of less toxic chemicals and less use of inorganic fertilizers are also pollinator friendly practices. The third category of pollinator friendly practices is managing for bee nest sites through no till agriculture, hand tillage, leaving dead trees and fallen branches undisturbed, avoidance of flood irrigation etc. The fourth category of pollinator friendly practices is use of managed pollinators through beekeeping and introducing nesting sites for bee pollinators (FAO, 2008). The present maize-pumpkin mix crop production practice under study could be treated as one of the important pollinator friendly practices as it has incorporated pollinator friendly cucurbit crop with extended flowering period and good forage for bees and other natural pollinators. Maize-pumpkin growing in mix crop pattern is traditional practice and the district is popular for maize production in all three crop production seasons. Maize-pumpkin mix crop production used in the study is for summer season maize production. The supply of maize is maintained through import at the huge cost of foreign exchange to meet the growing demand of maize in domestic market. While making production decision, farmers consider costs of production and yield which ultimately affect rate of adoption and sustainability of any crop. So, profitability study on maize-pumpkin mix crop production is expected to reveal valuable information relating to farms and farmers practicing this system of mix crop production. Resources used in any production activity are regarded as the inputs that drive the production process. A resource is said to be efficiently utilized when it is put to the best use possible and at minimum cost allowable. For this better and improved technologies could be helpful but, it is very essential to analyze whether farmers are making rational use of available resources. Farmers might use the resources rationally but not at the economic optimum level, which is mainly due to inadequate knowledge on resource optimization. As the aim of every agribusiness firm is to maximize profit whiles minimizing cost, it is pertinent to determine the efficiency of resource use. Furthermore, future of maize production in general and maize-

pumpkin mix crop production in particular in the study area depends very much on the awareness of its profitability and resources use efficiency in the context of growing competitive crops in summer season, specially with vegetable crops. Keeping this in view the study was undertaken to determine profitability and resource use efficiency of maize-pumpkin mix crop production for the promotion of livelihood of growers and forages for pollinators.

METHODOLOGY

The study was conducted at Chitwan district in Nepal where, Global Pollination Project (GPP-FAO) was successfully implemented for five years (2009-2014). Chitwan district is located in the central region of Nepal at geographical line of $27^0$35’ North to $84^0$30’ East Latitude and $27^0$35’ North to $84^0$30’ East Longitudes. The climatic situation of the district varies from sub-tropical to tropical giving favorable conditions for growing diverse crop species. Total area of the district is about 223839 ha, of which 25.3% is agricultural land (DADO, 2014). Six Village Development Committees (VDCs) namely Padampur and Jutpani from eastern Chitwan; Phulbari and Mangalpur from Central Chitwan; and Meghauli and Sukranagar from Western Chitwan were selected randomly. These VDCs were among the nine VDCs of GPP-FAO conducted in the district. Western and central parts of Chitwan are more popular in maize-pumpkin mix cropping. Two farmers' group formed under GPP for the promotion of pollination friendly practices, with size of twenty five members in each group were randomly selected from each VDC. Thus a total of 50 farmers from each VDC and 300 farmers in total were the number of farmers selected for study on different pollinator friendly agricultural practices adopting by farmers. These 300 farmers were studied for ten common pollinator friendly practices namely mustard production, buckwheat production, surface seeded mustard production, surface seeded buckwheat production, organic rice production, organic maize production, bitter gourd production, bee keeping, kitchen gardening and maize-pumpkin mix cropping. Among 300 farmers selected under study on pollination friendly practices, 53 were maize-pumpkin mix crop growers. Primary data were collected with the use of structured interview schedule using face to face interview technique in April, 2014. After the collection of necessary information it was coded and entered in SPSS data entry sheet and analyzed by using STATA 12. Collected data were analyzed with descriptive and quantitative methods. The budgeting technique employed in the study was the gross farm income and gross margin. All variable inputs like human labor, tractor labor, seed, inorganic fertilizers, irrigation and organic manures were considered and valued at current market prices to calculate cost of production.

Total variable cost = Clabor+ Ctractor and animal labour+Cseed+ Cfert + Cirri + Cmanure
Where, C_{labor} = Cost on human labor used (NRs./ha), $C_{tractor\ and\ animal\ labour}$ = Cost on tractor labor and bullock lalor used (NRs./ha), C_{seed} = Cost on seed (NRs./ha), C_{fert} = Cost on inorganic chemical fertilizers (NRs./ha), C_{irri} =Cost on irrigation (NRs./ha) and C_{manure} = Cost on organic manures (NRs./ha)

Gross return was calculated by multiplying the total volume of outputs from maize-pumpkin mix cropping by the average price of maize and vegetable forms of pumpkin at harvesting period (Dillon & Hardaker, 1993). Thus gross return and productivity were calculated as maize product

equivalent by expressing the value of outputs from pumpkin in terms of maize product. Gross margin calculation was done to have an estimate of the difference between the gross return and variable costs. Gross margin was calculated by using the method as given by Olukosi *et al*. (2006) using following formula;

Gross Margin (NRs./ha) = Gross return (NRs./ha) - Total variable cost (NRs./ha)

Furthermore average cost per Kilogram of maize product equivalent was calculated as the ratio of total variable cost (NRs.) to total production (kg). Similarly average gross margin (NRs./kg) was calculated as the ratio of gross margin(NRs./ha) to productivity (kg/ha).

Benefit cost ratio is the quick and easiest method to determine the economic performance of a business. It is a relative measure, which is used to compare benefit per unit of cost. Undiscounted benefit cost ratio was estimated as a ratio of gross return and total variable cost. Thus, the benefit cost analysis was carried out by using formula;

$$\text{B/C ratio} = \frac{\text{Gross return (NRs.)}}{\text{Total variable cost (NRs.)}}$$

Koutsoyiannis (1977) defined production function as a technical relationship between factor inputs and output. Cobb-Douglas type of production function was used to determine the contribution of different factors on production and to estimate the efficiency of the variable production inputs in maize-pumpkin mix crop production. It is most widely used multiplicative and non linear form of production function used in agricultural research and is convenient for the comparison of the partial elasticity coefficient (Prajneshu, 2008). The marginal productivity of factors, marginal rate of substitution and the efficiency of production can be calculated directly from parameters in Cobb-Douglas type of production function. Thus, Cobb-Douglas production function of the following form was fitted to examine the resource productivity, efficiency and return to scale.

$$Y= aX_1^{b1}\, X_2^{b2}\, X_3^{b3}\, X_4^{b4}\, X_5^{b5} e^u$$

Where, Y= Gross return (NRs./ha), X_1= Cost on human Labor (NRs./ha), X_2= Cost on tractor and bullock labor (NRs./ha), X_3= Cost on organic manures (NRs./ha), X_4= Cost on seed (NRs./ha), X5= Cost on irrigation and fertilizers (NRs./ha), e=Base of natural logarithm, u = Random disturbance term, a=Constant, and b1, b2, ..., b5=Coefficients of respective variables.

The Cobb-Douglas production function in the form expressed above was linearised in to logarithmic function with a view of getting a form amenable to practical purposes using Ordinary Least Square (OLS) technique as expressed below;

$$\ln Y= \ln a+b_1\ln X_1+b_2\ln X_2+b_3\ln X_3+b_4\ln X_4+u$$

Where, ln= Natural logarithm, and u= Error term

For the calculation of return to scale on maize-pumpkin mix crop production, coefficients from Cobb-Douglas production function was used and calculated using formula;

Return to scale (RTS)= $\sum bi$

Where, bi = Coefficient of i^{th} explanatory variables.

Return to scale with value greater than unity represents increasing return to scale, value equal to unity represents constant return to scale and vale less than unity represents decreasing return to scale. The allocative efficiency of a resource used was determined by the ratio of Marginal Value Product (MVP) of variable input and the Marginal Factor Cost (MFC) for the input and tested for its equality to one i.e. (MVP/MFC)=1. Following Goni *et al*. (2007) the efficiency of resource use was calculated as;

r= MVP/MFC

Where, r= Efficiency ratio, MVP= Marginal value product of a variable input and
MFC= Marginal factor cost.

The standard way to examine such efficiency is to compare MVP with the MFC of each variable input. If MFC_{Xi} divides MVP_{Xi}, the result will be equal to the value of MVP_{Xi} because MFC at all cases is equal to 1. As the MFC is price of input per unit, the MFCs of all the inputs will vary while calculating the ratio of MVP to MFC. However, the denominator will always be one, and therefore, the ratio will be equal to their respective MVP (Majumder *et al*., 2009). The marginal value productivity of a particular resource represents the additional to gross return in value term caused by an additional one unit of that resource, while other inputs are held constant. The most variable, perhaps the most useful estimate of MVP is obtained taking resources, as well as gross return at their geometric means (Dhawan & Bansal, 1977). Since all the variables of the model were measured in monetary term, the slope coefficients of the explanatory variables in the function represent the MVP, which was computed by multiplying the production coefficient (elasticity, in this particular case) of a given resource with the ratio of geometric mean value of output and input variables (Rabbani *et al*., 2013).

Therefore, MVP_{xi}= dy/dxi, which is the product of regression coefficient with ratio of geometric mean of gross return to the level of use of i^{th} resource.

According to the conventional neo-classical test of economic efficiency, decision rule for resource use efficiency is that a efficiency ratio (r) equal to unity indicates the optimum use of that factor, the ratio more than unity indicates that gross return could be increased by using more of the resource and the ratio of less than unity indicates the excess use of resource which should be decreased to minimize the loss (Eze, 2003; Mbansor, 2002; Olayide & Heady, 1982; Okon, 2005).

Again, the relative percentage change in MVP of each resource required to obtain optimal resource allocation, i.e. r=1 or MVP= MFC was estimated using the following equation below;

D= (1-MFC/MVP) × 100

Or, D= (1-1/r)× 100

Where, D= absolute value of percentage change in MVP of each resource and r
= efficiency ratio (Mijindadi, 1980).

RESULTS AND DISCUSSION

Cost of production

Human labor was an important and largely used input for growing maize-pumpkin mix crop. It was required for different operations such as land preparation, seed sowing, fertilizer application, harvesting, threshing. irrigation, cleaning etc. It was computed in terms of man day and converted to monetary term valuating at prevailing wage rate. The cost of human labor in production of maize-pumpkin in mix cropping system per hectare was estimated at about NRs. 16280 (Table 1). Labor cost accounted about 38% of total variable cost in maize-pumpkin mix crop production. It has shown that maize-pumpkin production activity in the study area is labor intensive. Tractor is labor saving modern tillage technology. In the study area, all the farmers used tractor or bullock as primary tillage equipment for their land preparation. Per hectare costs of tractor and bullock was about NRs. 9799, which accounted about 23% of total variable cost of maize-pumpkin production. Per hectare costs of organic manures was about NRs. 10672 which constituted about 25% of the total variable cost (Table 1). Major types of organic manures used in the study area were farm yard manure and poultry manure.

Almost all the farmers used chemical fertilizers, mainly urea and DAP. Per hectare costs of inorganic fertilizer was estimated at about NRs. 3950, which accounted about 9% of total variable cost. Similarly, few maize-pumpkin growers irrigate their crop as they used to grow in unirrigated land in summer season after winter crops. As regards the production from maize-pumpkin mix crop production, the per hectare cost on seed accounted about NRs. 2021, which constituted about 5% of total variable cost of production (Table 1).

Table 1: Average cost of production in maize-pumpkin mix cropping system (NRs./ha)

Items of cost	Mean	Percent of total cost
Human labor	16280.09	37.84
Machinery and animal labour	9798.63	22.77
Seed	2020.53	4.70
Organic manures	10671.54	24.80
Irrigation	307.03	0.71
Fertilizers	3950.34	9.18
Total cost	43028.16	100.00

Source: Field survey 2014

Returns from maize-pumpkin mix cropping

Farmers in the study area were practicing maize-pumpkin mix cropping on an average at 0.44 hectare of land with per hectare physical volume of output as 2.83 ton in maize equivalent basis (Table 2). The average farm gate price of maize was NRs. 2400 per quintal. Per hectare gross return and total variable cost were estimated at about NRs. 67955 and NRs. 43028, respectively. Per hectare gross margin of maize-pumpkin production was estimated at about NRs. 24927. Cost and gross margin were also estimated on per kilogram basis and they were estimated at NRs. 15.19 and NRs. 8.80, respectively. It was observed that the overall undiscounted benefit cost ratio considering total variable cost was 1.58. Thus, it was found that maize-pumpkin mix crop production was profitable in the study area.

Resource use efficiency on maize-pumpkin mix cropping

Agricultural production is the result of a combination of different inputs used. The individual effect of these inputs can be explained to certain degree by multiple regression analysis, but the isolation of the effect of each variable may be very difficult in tabular technique (Islam & Dewan, 1987). Estimated values of the coefficients and related statistics of Cobb-Douglas production function are shown in Table 3. Five explanatory variables namely human labor cost, tractor and bullock use cost, seed cost, organic manure cost and irrigation cum fertilizer costs were considered to show their effects on maize-pumpkin mix crop production. Out of these five variables organic manure cost and irrigation cum fertilizer cost and seed cost were significant at 1% level. The regression coefficient for organic manure cost was 0.151, which had depicted that with 100% increase in cost on organic manure, gross return could be increased by about 15%. Similarly, with the increase in seed cost by 100%, gross return from maize-pumpkin mix cropping could be increased by about 30% as its coefficient is 0.297, which might be resulted from the higher productivity contributed due to better seeds purchased at market. Expenditure on fertilizer and irrigation could increase the gross return by about 14% and with the increase in their use by 100%. Similar to this, Baloyi *et al*. (2012) using production function reported fertilizer, tractor power, labor and seed as significant factors on small scale maize production in South Africa. of cashew in Ghana.

Table 2: Economic statement of maize-pumpkin mix cropping in the study area

Measuring criteria	Average value
Area (ha.)	0.44
Productivity-maize equivalent (t/ha)	2.83
Gross return (NRs./ha)	67954.97
Total variable cost (NRs./ha)	43028.16
Gross margin (NRs./ha)	24926.81
Average cost (NRs./qt)	1519.65
Average revenue (NRs./kg)	2400.00
Average profit (Rs./qt)	880.35
Benefit cost ratio	1.58

Source: Field survey 2014

Table 3: Estimated value of coefficients and related statistics of Cobb-Douglas production function of maize-pumpkin mix cropping

Factors	Coefficient	Std. Error	t-value
Constant	3.755**	0.861	4.36
Human labor cost (NRs./ha)	0.085	0.086	0.99
Tractor and bullock cost (NRs./ha)	0.183	0.105	1.74
Organic manure cost (NRs./ha)	0.151**	0.052	2.89
Seed cost (NRs./ha)	0.297**	0.113	2.63
Cost on fertilizer and irrigation (NRs./ha)	0.141**	0.047	2.97
F-value	31.79**		
R square	0.771		
Adjusted R-square	0.747		
Return to scale	0.857		

Note: **Significant at 1% level of confidence

Source: Field survey 2014

The coefficient of multiple determination (R^2) is a summary measure which tells how well the sample regression line fits the data (Gujarati, 1995). The coefficient of multiple determination R^2 of the model was 0.771 for maize-pumpkin mix crop production. It indicates that about 77% of variations in gross return have been explained by the explanatory variables, which were included in the model. The value of adjusted R square was 0.747 indicating that after taking into account the degree of freedom (df) about 78% of the variation in the dependent variable explained by the explanatory variables included in the model. The measures of the overall significance of the estimated regression F value was 31.79 and it was significant at 1% level implying that all the explanatory variables included in the model are important for explaining the variation of the dependent variable in maize-pumpkin production.

The concept of return to scale was applied to the production function to determine the stages of production in which farmers were allocating their resources. Returns to scale reflect the degree to which a proportional change in all inputs caused proportional change in the output. The summation of all production coefficients indicate return to scale. The sum of the coefficients of different inputs stood at 0.857 for maize-pumpkin production. This indicates that the production function exhibited a decreasing return to scale implies that if all the inputs specified in the function are increased by 100% income will increase by about 86%. Similar to this the findings of Obasi (2007), Wosor & Nimoh (2012) and Rabbani *et al*. (2013) who have reported decreasing return to scale on arable crops, chilli and mustard production, respectively. Contrary to this Wongnaa & Ofori (2012), Saikumar *et al.* (2012) and Goni *et al.* (2007) have found the increasing return to scale on cashew production, tank command farming system and rice, respectively in Ghana, India and Nigeria. The estimated MVP of different inputs used in maize-pumpkin production is presented in Table 4. Given the level of technology and prices of both inputs and output, the study revealed that ratio of MVP to MFC of tractor and bullock cost, seed cost and expenditure on fertilizer and irrigation were positive and greater than one indicating their under-utilization. It had implied that more profit could be obtained by increasing on their level of use. Human labor input was over utilized as its efficiency ratio is smaller than unity. Study result showed that the efficiency ratio for organic manure cost was near to one and had revealed that it is optimally utilized in practical sense.

Table 4: Estimates of measures of allocative efficiency of inputs used in maize-pumpkin mix cropping

Inputs	Geometric mean	Coefficient	MVP	MFC	MVP/MFC	Efficiency	Percent adjustment required
Human labor cost (NRs./ha)	28516.45	0.085	0.200	1.00	0.200	Over utilized	399.789
Tractor and bullock cost (NRs./ha)	9697.51	0.183	1.267	1.00	1.267	Under utilized	21.056
Organic manure cost (NRs./ha)	10211.98	0.151	0.993	1.00	0.993	Over utilized	0.749
Seed cost (NRs./ha)	2004.80	0.297	9.944	1.00	9.944	Under utilized	89.944
Expenditure on fertilizer and irrigation (NRs./ha)	4218.97	0.141	2.243	1.00	2.243	Under utilized	55.424

Source: Field survey 2014

The adjustment in the MVPs for optimal resource use in Table 4 indicated that for optimal allocation of resources expenditure on seed and fertilizer cum irrigation were required to increase by about 90% and 55% respectively. The increase in the cost on seed has suggested for more expenditure on seed to purchase improved seed as compared with the own farm produced seed. Similar results of under utilization of fertilizer and seed were assessed by Gani & Omonana (2009) on the production of maize in Nigeria. But the results in this study were contrary for labor inputs. Chapke *et al*. (2011) also reported that for optimum allocation of resources about 88% increase in fertilizer and more than 30% increase in agrochemicals was needed for sorghum production in India but the results disagrees with the findings for adjustment on irrigation and seed inputs in the same study. Arriving to the concluding remarks, the study showed that maize-pumpkin production is a reasonably profitable enterprise, although its productivity is still low. However, higher gross return from per hectare of land can be realized by increasing the level of resources applied to maize-pumpkin mix crop production principally seed, fertilizer, irrigation and tractor power. The analysis of resource use efficiency on maize-pumpkin mix crop production shows that all the resources considered in the study are inefficiently utilized. Thus, to obtain economic advantage, farmers are to be encouraged for increase in underutilized inputs and reduce the use of over-utilized inputs. The level of adjustments for use of various resources to earn optimum returns will serve as a bench-mark guideline for the maize-pumpkin growers in the area, government agencies, and agro-based companies. Thus if proper uses of resources could be ensured, maize-pumpkin mix cropping could be a more viable and attractive commercial enterprise for the promotion of food, income, forage for pollinators and import substitution.

ACKNOWLEDGEMNETS

The authors express their gratitude to the GPP-FAO for the partial financial support to conduct this study. We would also like to express our deepest gratitude to our colleagues for their direct and indirect help for the completion of research and heartwarming appreciation goes to respondents of the study site for their cooperation, time and valuable information.

REFERENCES

Baloyi, R.T., Belete, A., Hlongwane, J. J., & Masuku, M. B. (2012). Technical efficiency in maize production by small-scale farmers in Ga-Mothiba of Limpopo province. *African Journal of Agricultural Research*,7(40),5478-5482.

Chapke, R.R., Mondal, B., & Mishra, J.S. (2011). Resource use efficiency of sorghum production in Rice- fallows in Andhra Pradesh. *Indian Journal of Human Ecology,* 34(2), 87-90.

DADO (2014). District Agriculture Development Office. Annual agricultural development program and statistical year book. District Agriculture Development Office, Bharatpur, Chitwan, Nepal.

Devkota, K. (2012). Economics of pollination and pollination management practices in Chitwan district, Nepal. M.Sc. thesis. Tribhuvan University, IAAS, Chitwan, Nepal.

Dhawan, K.C., & Bansal, P.K. (1977). Rationality of the use of various factors of production on different sizes of farm in the Punjab. *Indian Journal of Agricultural Economics,* 32(3), 121-130.

Dillon, J.L., & Hardaker, J.B. (1993). Farm management research for small farm development. Food and Agriculture Organization of the United Nations, Rome.

Eze, A.R., Amanze, B., & Nwankwo, O. (2010). Resource use efficiency in arable crop production in among smallholder farmers in Owerri agricultural zone of Imo state, Nigeria. *Researcher*, 2(5),14-20.

FAO (2008). Food and Agricultural Organization of the United Nations. Tools for conservation and use of pollination services: initial survey of good pollination practices. Food and Agriculture Organization of the United Nations, Rome.

Gani, B.S., & Omonona, B.T. (2009). Resource use efficiency among small scale irrigated maize producers in Northern Taraba State of Nigeria. *Journal of Human Ecology*, 28(2), 113-119.

Goni, M., Umar, M., & Sman, U. (2013). Analysis of resource-use efficiency in dry season vegetable production in Jere Borno State, Nigeria. *Journal of Biology and Agriculture Health*, 3(19), 18-23.

Goni, M., Mohammed, S., & Baba, B. A. (2007). Analysis of resource use efficiency in rice production in the Lake Chad area of Borno State, Nigeria. Journal of Sustainable *Development in Agriculture and Environment*, 3(2), 31-37.

Gordon, J., & Davis, L. (2003). Valuing honeybee pollination. Rural Industries Research and Development Corporation. Publication No. 03/077.

Gujarati, D.N. (2007). Basic Econometrics. Tata McGraw-Hill Ltd, New Delhi, India.

Islam, M.S., & Dewan, S. (1987). An economic analysis of pond fish production in some selected areas of Bangladesh. Bureau of Socioeconomic Research and Training, Bangladesh Agricultural University, Bangladesh.

Koutsoyiannis, A. (1977). Theory of Econometrics. The MacMillan Press Ltd., London.

Majumder, M.K., Mozumdar, L., & Roy, P.C. (2009). Productivity and resource use efficiency of Boro rice production. *Journal of Bangladesh Agricultural University*, 7(2),247-252.

Mbansor, J.A. (2002). Resource use pattern among poultry enterprises in Abia state, Nigeria. *Nigerian Journal of Animal Production*, 29(1), 64-70.

Mijindadi, N.B. (1980). Production efficiency on farms in northern Nigeria. PhD dissertation. Cornell University, USA.

MoAD, (2013). Ministry of Agriculture Development. Statistical Information on Nepalese Agriculture (2010/2011). Agribusiness Promotion and Statistics Division(ABPSD), Kathmandu, Nepal.

Obasi, P.C. (2007). Farm size productivity relationship among arable crop farmers in Imo state, Nigeria. *International Journal of Agriculture and Rural Development*, 9(91), 91-99.

Okon, E.T. (2005). Comparative analysis of large and small scale farmers resource use efficiency in food crop production in Akwa-Ibom state, Nigeria. *Journal of Agriculture and Food science*, 3(1), 75-84.

Olayide, S.O., & Heady, E.O. (1982). Introduction to agricultural production economics. University press, Ibadan.

Olukosi, J.O., Isitor, S.U., & Ode, M.O. (2006). Introduction to agricultural marketing and prices: principle and application. *American Journal of Agriculture and Forestry*, 2(4), 199-205.

Partap, T. (2001). Mountain agriculture, marginal land and sustainable livelihoods: Challenges and opportunities. International Symposium on Mountain Agriculture in HKH Region (May 21-24, 2001). International Centre for Integrated Mountain Development (ICIMOD), Kathmandu, Nepal.

Paudyal, K.R., & Poudel, S.K. (2001): Impact of public and private sector maize research in Nepal. In: impact of Public and Private Sector Maize Breeding research in Asia (1966–1999). CIMMYT, Mexico, D.F., pp. 66–80.

Prajneshu, (2008). Fitting of Cobb -Douglas production functions: revisited. *Agricultural Economics Research Review*, 21, 289-292.

Rabbani, M.G., Sheema, A.A., Islam, M.S., & Hasan, H.K. (2013). Profitability and resource use efficiency of mustard production: evidence of farmers' practices in Mymensingh District of Bangladesh. *International Journal of Applied Research in Business Administration and Economics*, 2(3), 37-46.

Saikumar, C., Bharamappanavara, S.M., Mundinamani, B.K., Naik & Kiresur, V.R. (2012). Resource use efficiency and constraints in farming in the tank commands: the case of north eastern Karnataka. *Journal of Rural Development* , 32(3), 311-320.

Verma, L.R. (1999). Beekeeping in integrated mountain development: economic and scientific perspectives. ICIMOD senior fellowship series, No. 4. Oxford and IBH Publishing Company Pvt. Ltd., New Delhi, India.

Wongnaa, C.A., & Ofori, D. (2012). Resource-use efficiency in cashew production in Wenchi Municipality, Ghana. *Agris On-line Papers in Economics and Informatics***,** 4,73-80.

Wosor, D.K., & Nimoh, F. (2012). Resource use efficiency in chili pepper production in the Keta municipality of Volta Region of Ghana. *Journal of Elixir Production Management* , 47, 8595-8598.

Journal of Maize Research and Development (2015) 1(1):123-133
ISSN: 2467-9305 (Online)/ 2467-9291 (Print)
DOI: 10.5281/zenodo.34289

Simulation of growth and yield of rainfed maize under varied agronomic management and changing climatic scenario in Nawalparasi, Nepal

Umesh Shrestha*[1], Lal Prasad Amgain[1], Tika Bahadur Karki[2], Khem Raj Dahal[1]

ARTICLE INFO

Article history:
Received:
7th May, 2015
Revised :
26th June, 2015
Accepted:
12th September, 2015

Keywords:
Spring maize, Sowing dates, Cultivars, Grain yield, CSM_CERES-Maize model, Climate Change

ABSTRACT

A field experiment and simulation modeling study in combination for different maize cultivars planted at different sowing dates were accomplished at Kawasoti-5, Nawalparasi during spring season of 2013 to assess the impact of climate change scenario as predicted by IPCC in rainfed spring maize by using CSM-CERES-Maize model. Result showed that RML-4/RML-17 produced higher kernel rows/ ear (13.77), kernel per row (30.42) and test weight (244.9 g). Significantly higher grain yield was also found for RML-4/RML-17 (6.03 t/ha) compared to Poshilo makai-1 (4.73 t/ha), Arun-2 (3.55 t/ha) and Local (2.92 t/ha). Earlier sowing date (7th April) actually produced higher kernel/row (27.97), kernel rows/ear (12.89) and 1000 grain weight (230 g). Significantly higher grain yield (5.13t/ha) was obtained in earlier sowing date (7th April). The CSM-CERES-Maize model was calibrated and found well validated with days to anthesis (RMSE= 0.426 day and D-index= 0.998), days to physiological maturity (RMSE=0.674 day and D-index= 0.999), number of grain/m^2 at maturity (RMSE= 85.287 grain /m^2 and D-index= 0.993), unit weight at maturity (RMSE=0.012 g/kernel and D-index= 0.854) and grain yield (RMSE=54.94 kg/haand D-index= 1.00). The model was found sensitive to climate change parameters. The sensitivity for various climate change parameter indicated that there was severely decreased trend in simulated rainfed spring maize yield with the increment of maximum and minimum temperature, decrease in solar radiation and decrease carbondioxide concentration. Even 2^0C rise in temperature can decrease around 15-20% yield of spring maize and this negative effect was even more pronounced in hybrid than other cultivars.

INTRODUCTION

Maize (*Zea mays* L.) is the second most important staple food crops both in term of area and production after rice in Nepal. It has the highest yield potential over other cereals and thus known as 'the queen of cereals' (Singh, 2002). It is grown in about 906253 ha land with 206772 metric tons total production and 2.33 mt/ha productivity (Agricultural Diary, 2069). Maize contributes 9.5% AGDP and 3.15% GDP (MoAD, 2012). Maize occupies about 28.32% of the total agricultural land cultivated, and shares about 23.89% of the total cereal production in Nepal (MoAC, 2009/10). The overall demand for maize will be increased by 6-8% per annum largely for the next two decades as a result of increased demand for food in hills and feeds in terai and inner terai and, this increased demand could only be met by increasing the productivity of maize per unit area of land (NMRP, 2009). The rainfed

Corresponding author Info:
M.Sc. Ag. Student
1Tribhuwan University, Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal
*2Nepal Agricultural Research Council, National Maize Research Program, Rampur, Chitwan, Nepal. *E-mail: friend_ship069@yahoo.com*

farming means the cultivation of crops on relatively dry land that lacks easy access to irrigation and moisture requirement at any growth and development stages of crop. Rainfed farming areas fall mainly in arid, semi arid and dry sub-humid zones in the world but the Nepalese sub-tropical region is also rainfed. In Nepal, about 65% of the total arable land is under rainfed (Thapa, 1995). The variation in rainfall under rainfed zone especially during spring season feels long dry spell, early withdrawal and also increasing temperature caused stressful environment to plant growth, all of which strongly influence the productivity level of maize. Through a series of observations and modeling studies, the Inter-Governmental Panal on Climate Change (IPCC) has shown that the earth temperature has increased by 0.74 ^{0}C between 1906 and 2005 due to increase in anthropogenic emissions of green house gases. By the end if this century, temperature increase is likely to be 1.8-4 ^{0}C (IPCC, 2007). This would lead to more frequent hot extremes, floods, droughts, cyclones and gradual recession of glaciers, which in turn would result in greater instability of flood production. The increase in GHGs was 70% between 1970 and 2008 (IPCC, 2007). The global increases in CO_2 concentration are due to use of fossil fuel and land use change, while those of methane and nitrous oxide are primarily due to agriculture. It has also been estimated that crop production loss in south Asia by 2100 AD could be 10-40% despite the beneficial effects of higher CO_2 on crop growth. Agriculture contributes the significant of green house gas emission in south Asia primarily due to CH_4 and N_2O emission from rise by the application of manure and nitrogenous fertilizer in to the soils. Simple adaptation strategies such as change in planting dates and varieties could also help in reducing the impacts of climate change to some extent. Cropping system model (CSM-CERES-Maize) is a decision support tool used widely to evaluate and/or forecast the effects of environmental conditions, management practices, and different genotypes on crop growth, development and yield (Asadi and Clement, 2003). Earlier version of the DSSAT model (ver. 4.5) have been evaluated across rice growing environment of Asia and Australia and their performance has been generally satisfactory, but variation exists (Timsina and Humphreys, 2003). Similarly, Pathak *et al.* (2002), Timsina *et al*. (2004), Amgain *et al.* (2006) and Amgain and Timsina (2007) evaluated the CERES-Rice model (ver. 4.0) for soil mineral N and loss processes from rice fields under Rice-Wheat systems for Dehli, Modipuram and Punhab in north-west India. In context of Nepal, the CERES-Maize model had not been tested over different locations of country except few studies conducted in maize, e.g, by Sapkota *et al.* (2008) in winter maize and Bhusal et al.(2008) in spring maize. In this context an attempt has been tried to study the field performance of different maize cultivars under different sowing dates and simulation results of CSM-CERES-Maize model on the growth and yield under changing climatic scenarios of sub-tropical condition of central Nepal.

MATERIALS AND METHODS

Field experimentation

The field experiment was conducted at kawasoti-5, Nawalparasi district on maize (*Zea mays* L.) during late spring (April to August) season, 2013. The area is located at 27^{0}66' N latitude and 84^{0}13'E longitude with an elevation of 220 M above mean sea level. The place is situated in humid sub tropical climate but resembles the foot hill and inner terai cllimate. During the cropping period, maximum temperature was recorded in May (Monthly average= 34.12 ^{0}C). After rainfall started from May, maximum temperature decreased slightly; however, minimum temperature was found increasing consistently and dropped slightly after July only. The highest minimum temperature was recorded during July (monthly average= 26.05 ^{0}C). Total rainfall received during research period (7th April to 27th August) was 2789.1 mm.The

experiment was carried out in two factorial randomized complete block design with three replications. The treatment consists of combination of four maize cultivars (Local, Poshilo makai-1, RML-4/RML-17 and Arun-2) and three sowing dates (7th April, 22nd April and 7th May). The soil of the research site was silt loam and slightly acidic to basic in soil reaction (pH 6.2-7.4). The recommended agronomic management practices were followed to accomplish the experimentation except the fertilizer treatments. Yield and yield attributing characters were recorded, tabulated and analyzed using MSTAT-C computer software and statistical package as mentioned by Gometz and Gometz (1984).

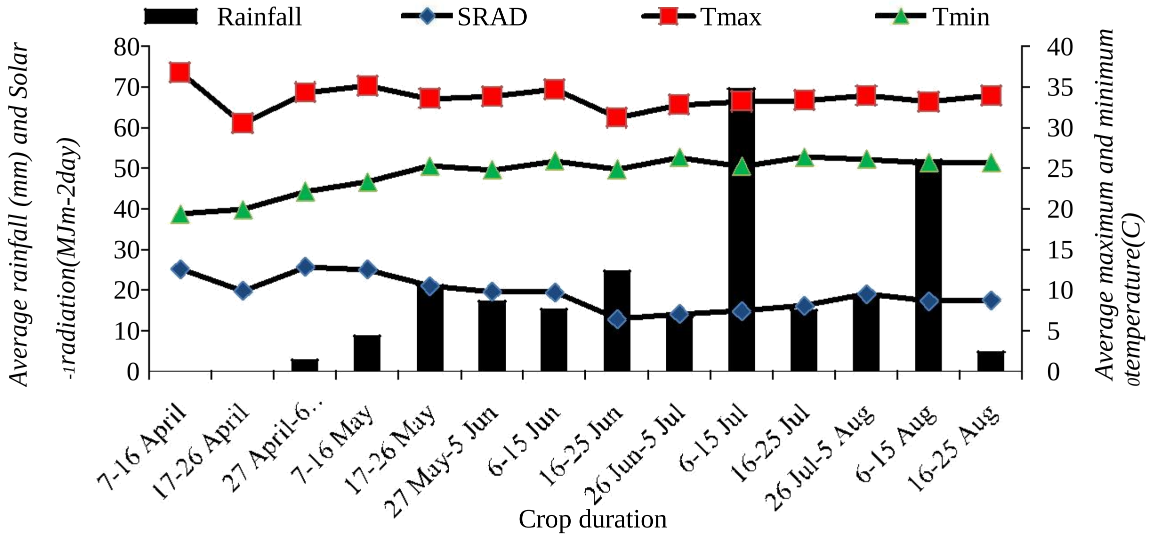


Figure 1. Average weather records during research period (10 days interval) at kawasoti-5, Nawalparasi, 2013 (Department of Hydrology and meteorology)

Simulation modeling

Various data on experimental field crops were taken in consideration for making appropriate input files required to run the DSSAT ver 4.5 crop models. Those characters include data sets required for experimental file (file X), yield attributes (file A), growth attributes (file T), Soil file (file S) and Weather file (file W). Model calibration was performed for all four maize cultivars those sown in 7th April. Model validation was done using maize cultivars planted in 22nd April and 7 th May. The parameters used for model validation were days to anthesis, day to physiological maturity, grain yield, unit grain weight and number of grain per unit area. Sensitivity analysis was accomplished using maize cultivars planted in 7th April. Simulation to different scenarios of climate change was completed altering maximum and minimum temperature by $\pm$ 2^0C, solar radiation by $\pm$ $1MJm^{-2}$/day and increasing carbon dioxide concentration by 20 ppm than present weather scenarios.

RESULTS AND DISCUSSION

Table 1 clearly indicated that number of ears/ha was insignificant for all sowing dates and maize cultivars. Kernel row/ear (12.89) and kernels/row (24.47) in 7th April planted maize were recorded highest followed by 22nd April and 7th April planted maize cultivars. It might be due to favorable temperature in early sown maize cultivar. A number of factors could be responsible for reduction in number of kernels per row under heat stress, such as reduced pollen viability and receptivity of silk, increased frequency of kernel abortion, decreased cell division in endosperm, reduced silk capacity of developing kernels, reduced starch grain

number and overall starch synthesis, increased soluble sugar accumulation, duration of grain filling, kernel development and enzyme activities (Duke and Doehlert, 1996). In case of cultivars, RML-4/RML-17 had highest kernel row ear-1 (13.77) and kernels/row (30.42) than other cultivars. The reason for best performance for most of the traits for hybrid might be due to added traits called heterosis. It is observed that maize 1000 grain weight were higher and statistically similar in maize planted 7th April (232.0 g) and 22nd April (231.3 g) than 7th May (224.3 g). Suwa *et al.* (2010) reported depression in source-sink activity under high temperatures. Heat stress decreased seed filling duration (Hellewell *et al.*, 1996; Prasad *et al.*, 2006) due to which test weight of 7th May sown cultivars were found less. Similarly, test weight of RML-4/RML-17 (244.9 g) and Poshilo Makai-1 (241.2 g) were found higher as these cultivars were long durational and had longer seed fill durations than short durational cultivars i.e, Local and Arun-2. Similarly, grain yield was found higher in 7th April (5.126 t/ha) followed by 22nd April (4.104 t/ha) and those planted in 7th May (3.692 t/ha) had least grain yield. High night temperatures result in loss of more sugars for respiration and reduce the availability for kernel filling, thereby lowering potential grain yield (Thomison, 2010). In case of maize cultivars, RML-4/RML-17 had highest grain yield as hybrid possess hybrid vigor. It had longer crop duration, high seed fill duration, long leaf stay green character, higher leaf area index etc. Unlike grain yield, 22nd April (14.26 t/ha) and 7th April (14.35 t/ha) sowing dates had higher stover yields. But, here also hybrid RML-4/RML-17 (17.18 t/ha) had highest stover yield than other cultivars.

While in case of harvest index, 7th April (0.347) planted maize cultivars had highest harvest index but remaining both sowing dates had similar and least harvest index. This finding was in agreement with Jasemi *et al.* (2013) who found harvest index was higher for plant sown on 22nd May than 13th July. But, in case of maize cultivars, both long durational cultivars had higher harvest index than short durational cultivar. It was due to longer seed fill duration, higher leaf area index, higher leaf area duration.

Model calibration

The genetic coefficients of maize cultivars were adjusted by running the model for 15 times with various possible changes in the genetic coefficients till the simulated values for parameters such as days to anthesis, days to physiological maturity, grain yield matches with observed values for maize cultivar planted in 7th April. The value such as 230 (P1). 0.520(P2), 940(P5), 360(G2), 9.28(G3) and 38.90(PHINT) were adjusted for Local; 400(P1), 0.600(P2), 1130(P5), 590.9(G2), 8.38(G3) and 18.90(PHINT) were adjusted for Poshilo makai-1; 380 (P1). 0.260(P2), 1290(P5),

816.9(G2), 7.36(G3) and 8.9(PHINT) were adjusted for RML-4/17; 230 (P1). 0.520(P2), 910(P5), 440(G2), 9.88(G3) and 38.90(PHINT) were adjusted for Arun-2.

Table 1.Effect of sowing dates and varieties on yield attributing characters of maize during spring, 2013 at Kawasoti-5, Nawalparasi

Factor	Number ofears/ ha	Kernel rows/ ear	Kernels/ row	1000 grain weight (g)	Grain yield at 15% MC (t/ha)	Stover yield(t/ha)	Harvest index
Sowing dates							
7th April	59070	12.89^{a}	27.97^{a}	232.0^{a}	5.126^{a}	14.35^{a}	0.347^{a}
22nd April	57590	12.47^{b}	24.47^{b}	231.3^{a}	4.104^{b}	14.26^{a}	0.289^{b}
7th May	58150	12.22^{c}	22.73^{c}	224.3^{b}	3.692^{c}	12.58^{b}	0.290^{b}
SEm $\pm$	800.7	0.075	0.301	1.686	0.078	0.289	0.009
LSD$_{0.05}$	NS	0.219	0.883	4.946	0.227	0.849	0.027
Varieties							
Local	59750	11.31^{d}	21.10^{d}	204.4^{c}	2.920^{d}	10.64^{d}	0.278^{b}
Poshilo makai-1	56540	13.17^{b}	26.13^{b}	241.2^{a}	4.725^{b}	14.47^{b}	0.326^{a}
RML-4/RML-17	58270	13.77^{a}	30.42^{a}	244.9^{a}	6.030^{a}	17.18^{a}	0.351^{a}
Arun-2	58520	11.86^{c}	22.58^{c}	226.3^{b}	3.554^{c}	12.62^{c}	0.282^{b}
SEm $\pm$	980.7	0.092	0.369	2.065	0.089	0.334	0.011
LSD$_{0.05}$	NS	0.268	1.082	6.058	0.262	0.980	0.033
CV %	4.76%	2.07%	4.16%	2.55%	6.23%	7.30%	9.15%

Means followed by common letter (s) within each column are statistically similar at LSD 0.05

Table 2. Genetic coefficients for maize cultivars

Coefficient	Local Cultivar	Poshilo makai-1	RML-4/RML17	Arun-2
P1	230	400	380	230
P2	0.520	0.600	0.260	0.520
P5	940	1130	1290	910
G2	360	590.9	816.9	440
G3	9.28	8.38	7.36	9.88
PHINT	38.90	18.90	8.9	38.90
Simulated				
Anthesis day	49	61	56	49
Physiological maturity day	94	114	116	92
Grain yield	3121	5933	7684	3765
Observed				
Anthesis day	49	61	56	49
Physiological maturity day	94	114	116	92
Grain yield	3124	5931	7685	3768

Model validation

Genetic coefficients of four maize cultivars determined through calibration of the model were used for validation of the model. Model evaluation was performed using RMSE and Index of agreement (D-index) as suggested by Willmott (1982) and Willmott *et al.* (1985). Model validation was done by comparing model performance against data collected on days to anthesis (RMSE= 0.426 and D-index= 0.998), physiological maturity (RMSE=0.674 day

and D-index= 0.999), number at maturity(RMSE= 85.287 grain m^{-2} and D-index= 0.993), unit weight at maturity (RMSE=0.012 g $kernel^{-1}$ and D-index= 0.854) and grain yield (RMSE=54.94 kg ha^{-1} and D-index= 1.00) for all eight treatments (22nd April and 7th May planted varieties).

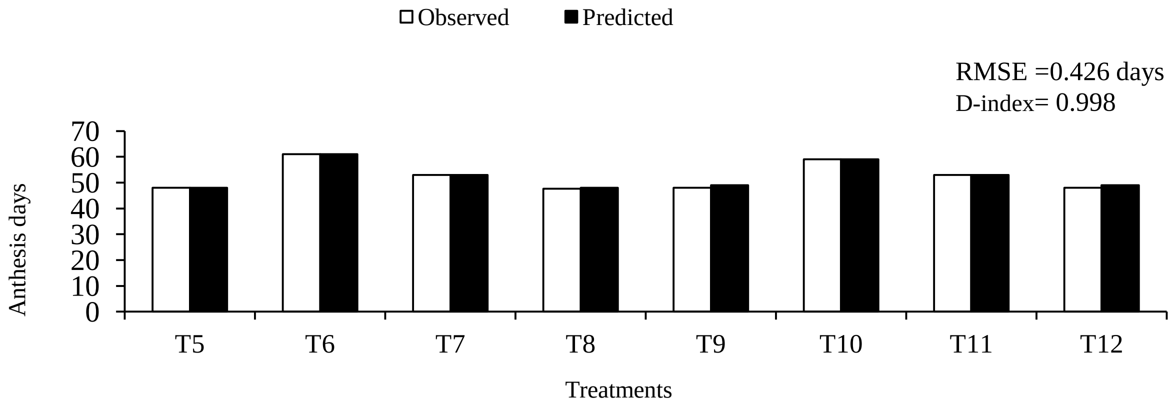


Figure 2. Simulated and observed anthesis days of various treatments

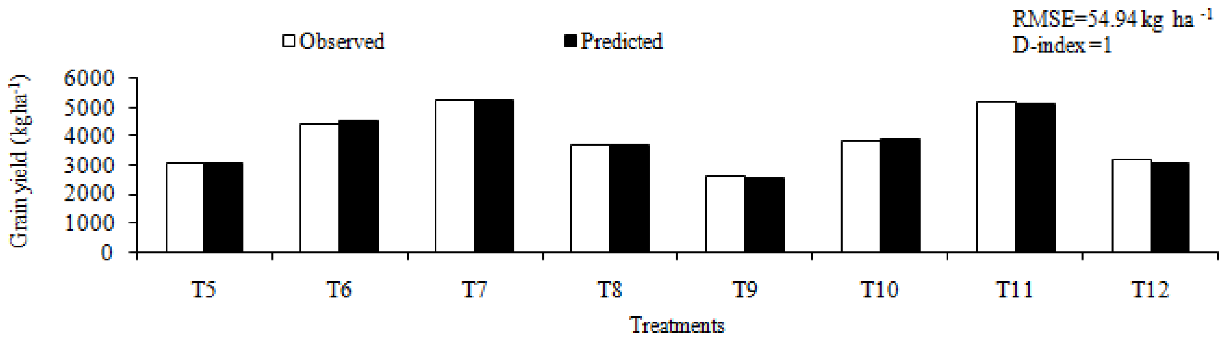


Figure 3. Simulated and observed physiological maturity days of various treatment

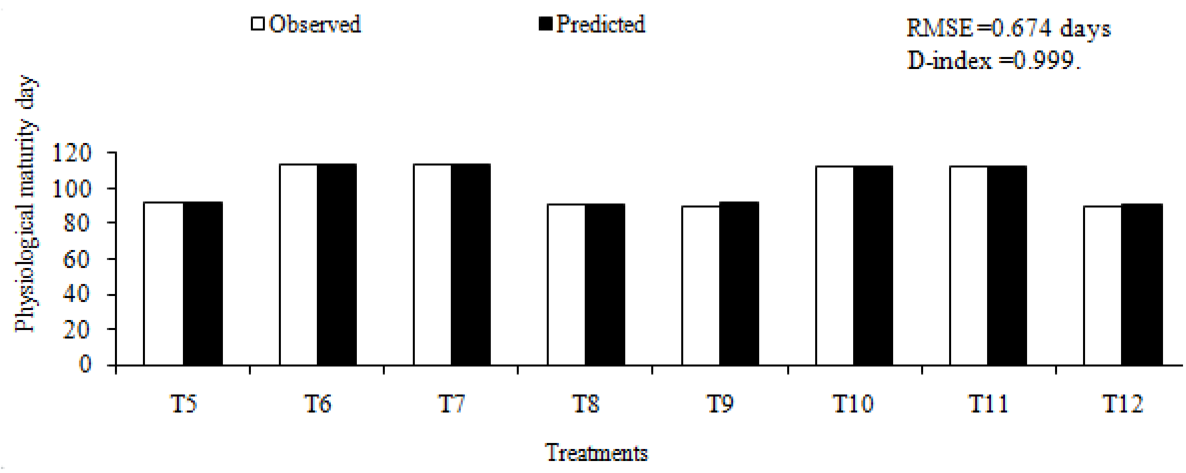


Figure 4. Simulated and observed grain yield of various treatments

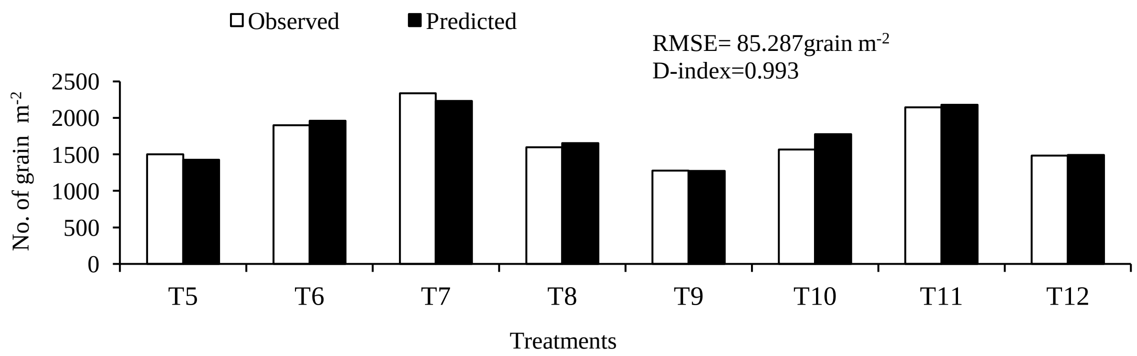


Figure 5. Simulated and observed number of grains per m^2 of various treatments

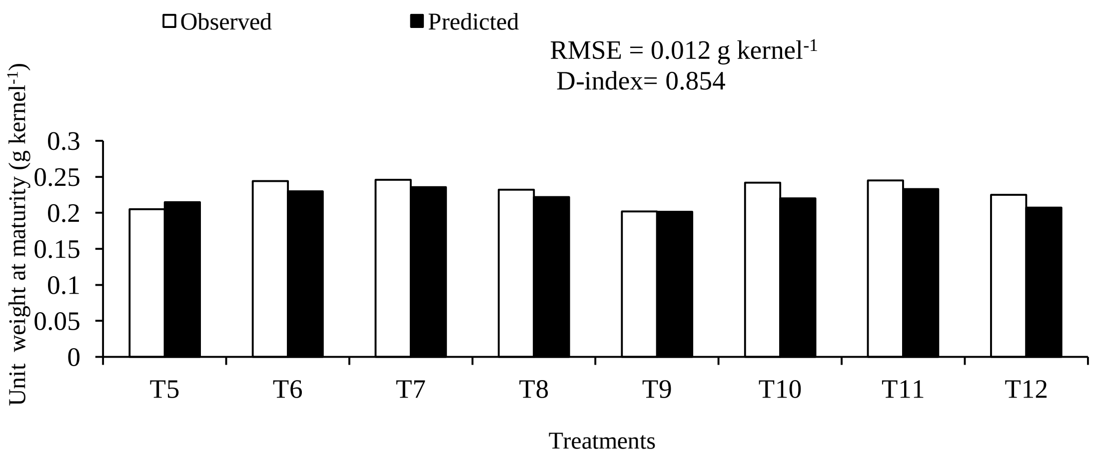


Figure 6. Simulated and observed unit weight at maturity for different various treatments

Table 3. Sensitivity analysis of maize cultivars with changes in temperature, solar radiation and CO2 concentration

Max Temp (^{0}C)	Min temp (^{0}C)	CO_2 Conc Ppm	Solar radiaton (MJ/m^2/day)	Variety	Simulated Grain yield	% yield change (kg/ha)	Growth duration (day)
+ 0	+0	380	+0	Local	3068	100	94
				Poshilo makai-1	5902	100	114
				RML-4/RML-17	7459	100	116
				Arun-2	3710	100	92
+2	+2	380	+0	Local	2697.69	-12.07	88
				Poshilo makai-1	4844.36	-17.92	106
				RML-4/RML-17	5966.45	-20.01	108
				Arun-2	3274.45	-11.74	87
-2	-2	380	+0	Local	3289.20	+7.21	101
				Poshilo makai-1	6810.32	+15.39	123
				RML-4/RML-17	8977.65	+20.36	126
				Arun-2	4181.17	12.70	99
+2	+2	+20	+0	Local	2733.59	-10.9	88
				Poshilo makai-1	4945.88	-16.2	106
				RML-4/RML-17	6093.26	-18.31	108
				Arun-2	3320.45	-10.5	87
-2	-2	+20	+0	Local	3381.24	+10.21	101
				Poshilo makai-1	6985.02	+18.35	123
				RML-4/RML-17	9126.83	+22.36	126
				Arun-2	4284.31	+15.48	99
+2	+2	+20	+1	Local	2792.49	-8.98	88
				Poshilo makai-1	5020.24	-14.94	106
				RML-4/RML-17	6225.28	-16.54	108
				Arun-2	3395.76	-8.47	87
+2	+2	+20	-1	Local	2677.44	-12.73	88
				Poshilo makai-1	4809.54	-18.51	106
				RML-4/RML-17	5958.99	-20.11	108
				Arun-2	3248.48	-12.44	87
-2	-2	+20	+1	Local	3591.09	+17.05	101
				Poshilo makai-1	7157.36	+21.27	123
				RML-4/RML-17	9591.53	+28.59	126
				Arun-2	4416.01	+19.03	99
-2	-2	+20	-1	Local	3299.32	+7.54	101
				Poshilo makai-1	6671.03	+13.03	123
				RML-4/RML-17	8597.99	+15.27	126
				Arun-2	4041.30	+8.93	99

Simulation to climate change parameters

The validated CSM-CERES Maize (Ver. 4.5) data were used to find sensitivity of model in Kawasoti-5, Nawalparasi. Validated CSM-CERES-Maize model was used to find out possible changes that can occur in rainfed spring maize that is grown in upland condition. The model was sensitive to climatic parameters (temperature, CO_2, concentration, solar radiation and rainfall) on yields of crops. Increments in both maximum and minimum temperatures by 2 ^{0}C, decreased yields of Local, Poshilo makai-1, RML-4/RML-17 and Arun-2 by -12.07, 17.92, -20.01 and -11.74 respectively as compared to base scenario with

current weather data. By increasing maximum and minimum temperature by 2 ^{0}C and carbondioxide concentration upto 20 ppm more, decreased yield 10.9, 16.2, 18.31 and 10.5 percent in Local, Poshilo makai-1, RML-4/RML-17 and Arun-2 respectively. Further more if solar radiation was increased by + 1 MJ/m^2/day then, yields of Local, Poshilo makai-1, RML-4/RML-17 and Arun-2 will be decreased by 8.98, 14.94, 16.54 and 8.47 percent respectively. Instead of increasing when solar radiation was decreased by 1 MJm^{-2}day$^-$1along with increased in both maximum and minimum temperature by 2 ^{0}C and carbondioxide by 20 ppm then yields of Local, Poshilo makai-1, RML-4/RML-17 and Arun-2 decreased by 12.73, 18.51, 20.11 and 12.44 respectively. But opposite consequences in yield of maize cultivars were noticed with reversing the phenomenon. When maximum and minimum temperature were decreased by 2 ^{0}C, increased yield of Local, Poshilo makai-1, RML-4/RML-17 and Arun-2 were noticed by following magnitudes; 7.21, 15.39, 20.36 and 12.70 percent respectively as compared with base scenario with current weather data. By deceasing mimimum and maximum temperature by 2 ^{0}C and increasing carbondioxide concentration upto 20 ppm more, increased yield 10.21, 18.35, 22.36 and 15.48 percent in Local, Poshilo makai-1, RML-4/RML-17 and Arun-2 respectively. But when decreased maximum and minimum temperature by 2 0C, increased carbondioxide by 20ppm and decreased solar radiation by 1 MJm^{-2}day^{-1} then yield of Local, Poshilo makai-1, RML-4/RML-17 and Arun-2 changed by 7.54, 13.03, 15.27 and 8.93 percent respectively. But instead of decreasing when solar radiation was increased by 1MJ/m^2/day then yield slightly increased by 17.05, 21.27, 28.59 and 19.03 percent respectively in Local, Poshilo makai-1, RML-4/RML-17 and Arun-2 respectively. The model was found to be sensitive to climate change parameters (temperature, solar radiation and CO2 concentration). Change in maximum and minimum temperatures ($\pm$2 ^{0}C), CO_2 concentration (+ 20 ppm from the base 380 ppm) with change in solar radiation ($\pm$1 MJ/m^2/day) resulted in much difference in grain yield. The result showed that with the decreasing scenarios of maximum and minimum temperature by 2^{0}C other factor remaining constant the yield of Local, Poshilo makai-1, RML-4/RML-17 and Arun-2 increased by 7.21%, 15.39%, 20.36% and 12.70% respectively. But when maximum and minimum temperature were increased by 2 ^{0}C than yield of Local, Poshilo makai-1, RML-4/RML-17 and Arun-2 decreased by 12.07%, 17.92%, 20.01% and 11.74% respectively. What we saw here was hybrid to be more sensitive to increased temperature than others. Higher temperature decreased the duration of growth and grain yield, despite high levels of radiation (Muchow et al, 1990).

CONCLUSION

Rainfed maize cultivation in late spring season is very risky. However, maize planted on 7th April had higher growth rate, higher yield and its attributing characters as it was facilitated by relatively favorable temperature. Among the cultivars, Hybrid (RML-4/RML-17) was noted best as it had higher grain and stover yield. Due to increasing temperature beyond optimum level, yield of maize cultivars planted in 22nd April and 7th May decreased by 20.015% and 27.975% respectively when compared with yield obtained from 7th April plantation. Changing climate has threatened rainfed spring maize cultivation. As temperature is increasing, under this changing scenario CSM-CERES-Maize model was used to evaluate its impact in spring maize production. We found yield of maize will decrease by 15-20 % if temperature increases by 2 ^{0}C and its impact was found even more serious in hybrid maize.

REFERENCES

Amgain, L.P., & Timsina, J. (2005). Major agronomical research work at the Institute of Agriculture and Animal Sciences, Rampur, Chitwan, Nepal: A Review. *J Inst Agric Anim Sci*, 25, 1-*22*.

Amgain, L.P., & Timsina, J. (2007). Simulation of yield, water and nitrogen balances in rice in Punjab, using CSM- CERESRice Model. *J Inst Agric Anim Sci*, 28, 15-26.

Asadi, M.E., & Clement, R.S. (2003). Evaluation of CERES-Maize of DSSAT model to simulate nitrate leaching, yield and soil moisture content under tropical conditions. *J Food Agri Eng Res,* 1(3/4), 270-276.

Bhusal, T.N., Amgain, L.P., Sah, S.K.,& Devkota, N.R. (2008). Effect of weather years, CO2 and climate change on yield of open pollinated varieties of maize at Rampur, Chitwan. 5th National Conference on Science and Technology, Nepal Academy of Science and Technology (NAST) (10-12 Nov, 2008), Kathmandu, Nepal.

Duke, E.R., & Dochlert, D.C. (1996). Effects of heat stress on emzyme activities and transcription levels in developing maize kernels growth in cultura. *Environ. Exp. Bot*., 36, 199-208.

Gometz, K., & Gometz, A.A. (1984) Statistical Procedures for Agricultural Research. John Wiley and Sons Inc, UK.

Hellewell, K.B., Stuthman, D.D., Markhart, A.H., & Erwin, J.E. (1996). Day and night temperature effects during grain filling in oat. *Crop Science*, 36, 624-628.

IPCC, (2007). Climate Change 2007: Climate Change Impacts, Adoptation and Vulnerability. Summary for Policy Makers, Inter-Governmental Panel on Climate Change.

Jasemi, M., Darabi, F., Naseri, R., Naserirad, H., & Bazdar, S. (2013). Effect of Planting Date and Nitrogen fertilizer application on grain yield and yield components in Maize (SC 704). American-Eurasian. *J. Agric. And Environ. Sci.*, 13(7), 914-919.

MoAC. (2010). Statistical Information on Nepalese Agriculture (2009/2010). Agribusiness Promotion and Statistics Division, Singh Durbar, Kathmandu, Nepal.

MoAD. (2012). Statistical Information on Nepalese Agriculture. Government of Nepal. Ministry of Agriculture and Cooperatives. Agri. Business Promotion and Statistics Division, Singh Durbar, Kathmandu, Nepal.

Muchow, R.C., Sinclair, T.R., & Bennett, J.M. (1990). Temperature and solar radiation effects on potential maize yields across locations. *Agron. J*., 82, 338-342.

NMRP. (2009). Annual Report, NARC, National Maize Research Program, Rampur, Chitwan, Nepal.

PV, V., Boote, K.J., Thomas, J.M.G., Allen, L.H., & Gorbet, D.W. (2006). Influence of soil temperature on seedling emergence and early growth of peanut cultivars in field conditions. *J. Agron.Crop Sci.*, 192, 168-177

Sapkota, A., Amgain, L.P, Devkota, N.R., & Timsina, J. (2008). Evaluation of CSM-CERES-Maize model, estimation of potential yield and yield gap analysis of winter maize at Rampur, Chitwan. *J Inst Agric Anim Sci*, 29, 27-32.

Singh, C. (2002). Modern techniques of raising field crops. Oxford and IBH Publishing Co. Pvt. Ltd. New Dehli, India.

Suwa, R., & Mohapatra, P.K. (2010). High temperature effects on photosynthate partitioning and sugar metabolism during ear expansion in maize (*Zea mays* L.) genotypes. *Plant Physiol. Biochem,* 48, 124-130.

Thapa, G. B. (1995). Projections and policy implications of food supply and demand in Nepal to the year 2020. Research Report Series No. 30, Winrock International Policy Analysis in Agriculture and Related Resource Management, Kathmandu, Nepal: APROSC.

Thomison, P. (2010). Has cool weather hurt corn yield? In: C.O.R.N Newsletter. The Ohio State University.

Timsina, J., Pathak, H., Humphreys, E., Godwin, D., Singh, B., Shukla, A.K., & Singh, U. (2004). Evaluation of, and yield gap analysis in rice using, CERES Rice ver. 4.1 in northwest India. Abstract of the 4th International Crop Science Congress, Brisbane, Australia, 26 Sept.-1 Oct. 2004. 170p.

Willmott, C.J. (1982). Some comments on the evaluation of model performance. *Bull. Am. Meteorol. Soc*, 63, 1309-1313.

Journal of Maize Research and Development (2015) 1(1):134-145

ISSN: 2467-9305 (Online)/ 2467-9291 (Print)
DOI: 10.5281/zenodo.34263

Analysis of chlorophyll content and its correlation with yield attributing traits on early varieties of maize (*Zea mays* L.)

Bikal Ghimire[*1], Deepika Timsina[1] and Jyotsna Nepal[1]

ARTICLE INFO

Article history:
Received:
5th April, 2015
Revised:
7th September, 2015
Accepted:
6th November, 2015

Keywords:
Maize, correlation coefficient, chlorophyll content

ABSTRACT

Chlorophyll has direct roles on photosynthesis and hence closely relates to capacity for photosynthesis, development and yield of crops. With object to explore the roles of chlorophyll content and its relation with other yield attributing traits a field research was conducted using fourteen early genotypes of maize in RCBD design with three replications. Observations were made for Soil Plant Analysis Development (SPAD) reading, ear weight, number of kernel row/ear, number of kernel/row, five hundred kernel weight and grain yield/hectare and these traits were analyzed using Analysis of Variance (ANOVA) and correlation coefficient analysis. SPAD reading showed a non-significant variation among the genotypes while it revealed significant correlation with no. of kernel/row, grain yield/hectare and highly significant correlation with no. of kernel row/ear and ear weight which are the most yield determinative traits. For the trait grain yield/ha followed by number of kernel row/ear genotype ARUN-1EV has been found comparatively superior to ARUN-2 (standard check). Grain Yield/hectare was highly heritable (>0.6) while no. of kernel / row, SPAD reading, ear weight, number of kernel row/ear were moderately heritable (0.3-0.6). Correlation analysis and ANOVA revealed ARUN-1EV, comparatively superior to ARUN-2(standard check), had higher SPAD reading than mean SPAD reading with significant correlation with no. of kernel/row, no. of kernel row/ear, ear weight and grain yield/ha which are all yield determinative traits . This showed positive and significant effect of chlorophyll content in grain yield of the maize.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops of the world. It has remarkable production potential in Nepal and is the second staple food in Nepal after paddy. After paddy, maize is important cereal crop of Nepal after rice in terms of area, production and productivity (MoAD, 2013/14). At present, the Maize sown area in Nepal is 9,28,761 ha and total production is 22,83,222 metric tons with productivity of 2458 Kg/ha (MoAD, 2014). In Chitwan, maize covers total area of 9750 ha with the total production of 29,250 metric tons and productivity of 3,000 Kg/ ha (MoAD, 2014). Chitwan is a terai area and out of total maize cultivated area in Terai region, 95.95 % area is under

Corresponding author Info:
[1]*Tribhuwan University, Institute of Agriculture and Animal Science (IAAS), Rampur Campus, Rampur, Chitwan, Nepal*
* *Email: anzealex@gmail.com*
Contact number: +9779845180818

improved and 4.05 % area under local maize. Maize exhibit sequential order of yield components development namely number of ear/plant, number of kernel/row, number of kernel row/ ear and hundred kernel weights (Viola *et al.*, 2004). There has been various study by different scholars about the yield attributing traits in maize. Among them chlorophyll content is one of the important attributing trait as it relates to photosynthesis capacity and stages of crop development. It is an important matter to study chlorophyll content and its significant roles in yield and production of maize in developing country like Nepal where there has not been much study in molecular level in case of maize and maize breeding. Chlorophyll accounted for more than 98% of gross primary production variation in maize (Gitelson *et al.*, 2008). The chlorophyll content of leaf has been suggested as the community property and has proportional relation to predict productivity. Not much information about the combining ability and genetic parameters about chlorophyll content of three-ear-leaves has been available yet. However, to evaluate the combining ability, reciprocal effect and genetic parameters for chlorophyll content of three-ear-leaves and how is it correlated with maize yield and other yield attributing traits was the objective of this research. By measuring the chlorophyll content, we can indirectly assess the potential taking up infrared radiation and the ability of a leaf to stay green (Araus *et al.*, 2008). The ratio of absorbance of radiation at 650 nm (chlorophyll absorbance peak) and at 940 nm (non-chlorophyll absorbance) can be calculated by Soil Plant Analysis Development (SPAD) meter SPAD-502. SPAD reading shows a positive relation with yield in maize as a result of transport of energy from photosynthesis due to increased production or shows negative relation with yield if energy is remobilized from chlorophyll. Any crop improvement is influenced by both genotypic variation and phenotypic variation. Degree of variability is an essential tool for effective selection. The phenotypic variation is affected by genotypic variation, environmental variation and interactions of both kinds (Lee & Lamkey, 2006). The total variance of a given character is its phenotypic variance (σ^2_p) and environmental variance ($\sigma^2 e$) attributed to environmental conditions. Determination of genotypic and phenotypic correlation is very fundamental step in the formulation and implementation of various breeding programs and activities. Correlation measures the degree of association, genetic or non-genetic, between two or more characters and is measured by a correlation coefficient (Hallauer & Miranda, 1988). In plant breeding, generally two types of correlations are discussed viz. genotypic correlation and phenotypic correlation. Phenotypic correlation (r_p) encompasses both genetic and environmental effects while the association of breeding values (i.e., additive genetic variance) of the two characters is genotypic correlation. Both of the correlations measure the extent how closely linked genes cause co-variation in two different characters (Hallauer & Miranda, 1988).The study was conducted to determine how chlorophyll content of three ear leaf plays role in maize yield and how it is correlated with other yield attributing traits. The research was conducted by taking fourteen genotypes including one standard check variety with following objectives:

- To study the chlorophyll content and its roles on maize productivity
- To study the correlation between chlorophyll content and other yield attributing traits of maize.

MATERIALS AND METHODS

Research site

Field experiment was conducted at research field of National Maize Research Program (NMRP) from 2 2 n d October 2014 to 12th April, 2015. The location is at 27°37′ N latitude and 84°25′E longitude with an elevation of 228 meters above sea level (NMRP, Rampur).

Climatic condition and season

The research site was climatically humid and sub-tropical. The average annual rainfall was 2000 mm (NMRP, Rampur). The meteorological data (Figure 1) were obtained from meteorological station, National Maize Research Program, (NMRP), Rampur.

Experimental details/materials/selection of genotype

Randomized Complete Block Design (RCBD) was laid with three replications and fourteen maize genotypes as treatments. These genotypes were allocated randomly to the fourteen plots of each replication. The plot size was 5.0 m × 3m with inter row spacing of 75cm and and intra row spacing of 25 cm, respectively. Each genotype was sown in each plot with four rows each of 5 m length. All genotypes were obtained from NMRP, Rampur. Following are the genotypes used in the research:

Entry no.	Genotype	Entry no.	Genotype
1.	ACROSS- 2401	8.	ARUN-2(standard check)
2.	RAJAHAR LOCAL	9.	FARMERS VARIETY
3.	S97TEYGHAYB(3)	10.	ZM-621/POOL-15
4.	POP-445/POP-446	11.	EEYC1
5.	ARUN-1EV	12.	KY/Pool-17
6.	R.C/POOL-17	13.	Pool-27
7.	SO3TETEY/LN	14.	Pool-15

Crop management

Land preparation was performed by ploughing two times followed by land leveling. Farm yard manure (FYM) was applied at the rate of 10 tons/ha and chemical fertilizers as per general recommendation for maize were applied at the rate of 120:60:40 NPK kg/ha of Nitrogen, Phosphorus and potassium respectively. Full dose of Phosphorus, Potassium and half dose of Nitrogen were applied at the time of sowing as basal application. Sowing was done on 22nd October, 2014 by manually operated sowing machine. Other half dose of Nitrogen was applied in splits of two doses doses during first and second weeding. Two hand weedings were carried out at 20-25 DAS. Thinning was done during first 15- 20 DAS. Earthing up was done as second weeding. The maize borer was controlled by placing granules of Phorate in top folding leaf. Phorate is an organophosphate used as an insecticide and acaricide.

Data collection

All the observation was recorded from five randomly selected plants of each plot and average

values were taken for analysis. Observations were taken for major traits viz. SPAD measures, number of kernels per row, number of kernel rows per ear, ear weight (gm), 500 kernel weight (gm) and grain yield per hectare with moisture adjustment at 14%.

Chlorophyll Nitrogen implying SPAD measures (SPAD reading)

Chlorophyll content o f l e a f was measured by using Soil Plant Analysis Development (SPAD) meter (SPAD 502, Minolta, Japan). Five plants were randomly selected from each plot to measure chlorophyll content.

Number of kernels/row

Number of kernels/ row was counted and recorded for five randomly selected ear and average value was taken.

Number of kernel row/ear

Number of kernel rows/ ear was counted and recorded for five randomly selected ear and average value was taken.

Ear Weight (gm)

Ear weight was measured after harvesting the cob and its weight was measured for individual cob.

Five-Hundred kernel weights (g)

Five Hundred kernel weights of samples was recorded along with their moisture content by using moisture meter and then it was converted to fourteen percent (14%) moisture content by using formula:

$$\text{500-Kernel weight} = \frac{100 - \text{Moisture content \%}}{\text{100-Required moisture\% (14\%)}} \times (\text{500-kernel weight})$$

Grain yield

To calculate grain yield, yield/plot was converted into grain yield/ ha. Grain Yield/ plot was converted to 14% moisture by using formula as above and then it was converted to grain yield/ha at 14% moisture by using given formula:

$$GY = \frac{\text{Yield / plot at 14\% moisture (kg)}}{\text{Plot size in } m^2} \times 10000\ m^2$$

Phenotypic and genotypic variance

Formula given by (Lush, 1940) and (Chaudhary & Prasad, 1968) was used to calculate phenotypic and genotypic variance.

Genotypic variance = $\sigma^2 g$ = (TMSS – EMSS) / R

Error variance = $\sigma^2 e$

Phenotypic variance = $\sigma^2 p = \sigma^2 g + \sigma^2 e$

Where,

TMSS is treatment mean sum of square
EMSS is error mean sum of square
R is number of replication

Genotypic and phenotypic coefficient of variation (GCV and PCV)

They are expressed as percentage. According to (Burton & Devane, 2008):
Genotypic coefficient of variation (GCV) = $(\sigma g/\bar{X}) \times 100$
Phenotypic coefficient of variation (PCV) = $(\sigma p/\bar{X}) \times 100$
Where,
σg = Genotypic standard deviation
σp = Phenotypic standard deviation
$\bar{X}$ = General mean of the trait

As indicated by (Sivasubramanjan & Menon, 1973), GCV and PCV are categorized as follows:
0 – 10 % : Low
10 – 20 % : Moderate
>20 % : High

Broad sense heritability (h_{bs}^2)

Hanson *et al* . , (1956) estimated broad sense heritability as the ratio of genotypic variance (V_g) to the phenotypic variance (V_p) and expressed in percentage.

Broad sense heritability (h_{bs}^2) = (V_g/V_p)

Robinson *et al.*, (1949) categorized broad sense heritability as follows:
0 – 0.30 : Low
0.30 – 0.60 : Moderate
> 0.60 : High

Genetic advance (GA)

It was calculated by using the following formula given by (Robinson *et al.*, 1949).

$$GA = i.\ \sigma p . h_{bs}^2$$

Where,
i = Efficacy of selection (2.06 at 5% selection intensity)
σp = Phenotypic standard deviation
h_{bs}^2 = Broad Sense Heritability

Genetic advance as percent of means (GAM)

GA as per cent of mean (GAM) = $(GA/\bar{X}) \times 100$
GA = Genetic advance
$\bar{X}$ =General mean of the trait

Johnson *et al.*, (1955) categorized GAM as follows:
0 - 10 % : Low
10 -20 % : Moderate
> 20 % : High

Statistical analysis

Analysis of variance was carried out by using statistical software GENSTAT, MINITAB version 20 as well as correlation analysis was done using SPSS version 21.

RESULTS AND DISCUSSION

Mean performance and analysis of variance

Mean values and significant levels of yield and yield attributing traits of fourteen maize germplasm are presented in Table 1. Significant results were observed for the for the traits grain yield/ha, ear weight, number of kernel/row, number of row kernel / ear, while non significant result was observed for SPAD reading and five hundred kernel weight.

Chlorophyll nitrogen implying SPAD measures (SPAD reading)

A non-significant difference ($P \leq 0.05$) in SPAD was found for the genotypes (Table 1). Maximum SPAD (51.74) had been showed by ARUN-2 (standard check) and minimum SPAD (44.59) had been showed by Pool-27.

Number of kernel rows/ear (NKRE)

The result showed significant difference ($P \leq 0.05$) in NKRE for the genotypes (Table 1). Maximum NKRPE (13.07) has been shown by ZM-621/POOL-15 and minimum (9.60) has been shown by KY/Pool-17.

Number of kernel/row (NKPR)

The result showed significant difference ($P \leq 0.05$) in NKPR for the genotypes (Table 1). Maximum NKPR (23.67) has been showed by FARMERS VARIETY and minimum (15.07) has been showed by KY/Pool-17. Variety S97TEYGHAYB(3), FARMERS VARIETY, ZM-621/POOL-15 , RAJAHAR LOCAL, POP-445/POP-446, ARUN-1EV, R.C/POOL-17, SO3TETEY/LN , EEYC1, Pool-27, Pool-15 were statistically similar to ARUN-2 (standard check) (Table 1).

Five Hundred kernel weights (FHKW)

The result showed that there was non-significant difference ($P \leq 0.05$) in FHKW for the genotypes (Table 1). Maximum FHKW (150.7) has been showed by ACROSS-2401 and minimum (112.0) has been showed by RAJAHAR LOCAL.

Grain yield Kg/Hectare (GYPH)

The result showed that there was significant difference ($P \leq 0.05$) in the grain yield kg/ha for the genotypes (Table 1). Among the tested genotypes ARUN-1EV has been found high yielder with grain yield of 2376 kg/ha and genotype KY/pool-17 with 164 kg/ha was low yielder genotype (Figure 2). The genotypes ARUN-1EV, S97TEYGHAYB (3), Farmers variety , SO3TETEY/LN, Pool-15, POP-445/POP-446 were found statistically at par with ARUN-2 (standard check) for grain yield kg/ha. The grain yield/ha in relation to genotypes has been shown in figure 2.

Broad sense heritability (hbs^2)

The considerable differences in heritability value for different characters were observed (Table 2). Among quantitative characters, high heritability (>0.60) has been observed for grain yield/ha

(0.67), Moderate heritability (0.30 to 0.60) has been found for number of kernel/row (0.344), SPAD reading (0.118), ear weight (0.45), number of kernel row/ear (0.376) while low heritability (<0.30) has been observed in five hundred kernel weight. (Viola *et al.*, 2004) reported high heritability for grain yield/ha which is very consistent with our finding. Grain yield/ha and ear height had better genotypic variability; better broad sense heritability along with better GA is considered the good estimates for effective selection of a trait. This depicted that visual selection based on these traits among the genotypes would be used for improvement of grain yield.

Genetic advance as percentage of mean (GAM)

GAM at five percent selection intensity exhibited greater differences for quantitative characters as represented in Table 2. High GAM having value more than 20% were estimated for ear weight and grain yield/ha. GAM between 10 and 20 % has been observed for number of kernel / row. Lower values were estimated for five hundred kernel weights, number of kernel row/ear, SPAD reading and ear length. GAM showed that ear weight, plant height and grain yield/ha were under control of additive genes. Alvi *et al.*, (2003) reported similar findings.

Phenotypic Coefficient of Variation and genotypic coefficient of variation (PCV and GCV)

The considerable difference in PCV and GCV values for different traits has been observed (Table 2). Among the studied quantitative traits, PCV and GCV values were estimated higher for grain yield/ha, ear weight had high PCV and moderate GCV, whereas five hundred kernel weights, number of kernel/row had moderate PCV values And number of kernel row/ear, SPAD reading had lower PCV and GCV value. The difference between GCV and PCV ranged from 3.747 to 10.913 and was lower for all traits studied. This showed the higher genetic effects in these parameters for variation. Higher broad sense heritability of all traits revealed that larger portion of variations is heritable to offspring.

Correlation coefficient

Analysis of correlation coefficient of yield related traits revealed some fundamental basis. Regression equation showed the relationship between the grain yield/ha with variables i.e. SPAD reading, number of kernel row/ear, number of kernel/row, ear weight and five hundred kernel weights. All traits showed positive correlation with grain yield/ha (Figure 3). This means that grain yield per hectare increases with increase in value of SPAD reading, number of kernel rows/ear, number of kernel/row, ear weight and five hundred kernel weight. Ibitome (2010) and Rafique et al. (2004) reported similar findings. Chlorophyll content by SPAD reading was found significantly correlated with number of kernel/row and number of kernel row/ear, ear weight were highly significant with SPAD reading. Thus, these traits have highly significant correlation with grain yield / hectare. The high direct effect of SPAD reading, number of kernel row/ear, number of kernel/row and ear weight appeared to be the main factor for their strong association with grain yield/plant. Hence direct selection for these traits would be effective. The traits grain yield/ha, number of kernel/row have shown higher heritability and also expressed highly positive and significant correlation coefficient. Thus, these traits are to be considered in selecting genotypes for better crop improvement and breeding programs.

CONCLUSION

Chlorophyll content and its correlation with yield attributing traits among the different maize genotypes was observed from this study which is very useful for their improvement of

agronomically important traits. Grain yield is the very complex parameter in Maize. Any minor change in any component leads to the yield loss. Grain yield and related traits are very sensitive to any crops. Association of different yield and yield attributing traits are very important to know their direct and indirect effects on grain yield. In this study we emphasized to determine the correlation coefficient of the traits with chlorophyll content in order to understand and identify how chlorophyll play a vital role in selection and breeding for simultaneous improvement of genetic materials. For the trait grain yield ha^{-1} followed by number of kernel row/ear, ARUN-1EV has been found comparatively superior to ARUN-2(standard check). For yield attributing traits like number of kernel row/ear, number of kernel/row and five hundred kernel weight genotype SO3TETEY/LN, FARMERS VARIETY and ACROSS-2401 showed highest value respectively. Grain Yeild Per hectare was highly heritable .Similarly, SPAD reading, no. of kernel per row, number of kernel row per ear, ear weight were moderately heritable. Higher GCV and high GAM indicate efficient indirect selection for higher grain yield/ha based on these traits. Thus high GAM and GCV was observed in ear weight ,grain yield per hectare and ear height. Correlation analysis revealed that the traits number of kernel row per ear , no. of kernel per row and ear weight were the most yield determinative traits and hence, selection of these traits for further breeding program might bring an improvement in grain yield. SPAD reading for chlorophyll content showed positive significant correlation with grain yield. Correlation analysis and ANNOVA revealed ARUN-1EV, comparatively superior to ARUN-2 (standard check), had higher SPAD reading than mean SPAD reading with significant correlation with no. of kernel/row, no. of kernel row/ear, ear weight and grain yield/ha which are all yield determinative traits . This showed positive and significant effect of chlorophyll content in grain yield of the maize. Besides the correlation *inter se* associations also provide huge support on these six traits from all other yield related components. The variability shown by different genotypes for different yield attributing quantitative traits can be used for the development of the high yielding and better performing variety. From the research, selection of ARUN-1EV genotype was found to be reliable for further research and breeding program in early varieties of maize. SPAD reading exhibiting chlorophyll content was found significantly correlated with grain yield and yield attributing traits.

Table 1.Means different parameters of fourteen maize genotypes in Chitwan, Nepal, 2014/15

		Mean				
Genotype	SPAD	NKRPE	NKPR	EW(gm)	FHKW(gm)	GYPH(kg)
ACROSS- 2401	47.81	11.60^{a}	17.53^{bc}	64.7^{bcd}	150.7	493^{ef}
RAJAHAR LOCAL	47.17	12.40^{a}	19.80^{ab}	61.4^{cd}	112.0	728^{def}
S97TEYGHAYB(3)	45.37	12.67^{a}	23.13^{a}	81.1^{abc}	120.7	2222^{a}
POP-445/POP-446	48.01	12.67a	20.73^{ab}	76.1^{abc}	122.0	1922^{abc}
ARUN-1EV	48.53	12.13^{a}	21.67^{ab}	86.0^{ab}	134.0	2376^{a}
R.C/POOL-17	45.27	11.60^{a}	19.33^{abc}	61.1^{cd}	116.7	711^{def}
SO3TETEY/LN	50.00	12.53^{a}	21.13^{ab}	87.2^{ab}	138.7	2175^{ab}
ARUN-2(std check)	51.74	11.60^{a}	23.33^{a}	93.9^{a}	140.7	2232^{a}
FARMERS VARIETY	49.59	11.33^{a}	23.67^{a}	88.7^{ab}	132.7	1982^{ab}
ZM-621/POOL-15	48.96	13.07^{a}	20.53^{ab}	73.2^{abc}	117.3	820^{def}
EEYC1	46.96	12.40^{a}	21.93^{ab}	81.3^{abc}	126.0	1073^{cdef}
KY/Pool-17	46.01	9.60^{b}	15.07^{c}	49.2^{d}	119.0	164^{f}
Pool-27	44.59	11.33^{a}	20.93^{ab}	64.7^{bcd}	123.3	1278^{bcde}

Pool-15	51.58	12.67^{a}	20.67^{ab}	88.3^{ab}	130.0	1598^{abcd}
Grand mean	47.97	11.97	20.68	75.5	127.4	1412
SEM (±)	1.907	0.529	1.434	7.20	9.97	281.5
$LSD_{0.05}$	ns	1.537*	4.169*	20.92**	ns	818.4**
CV %	6.9	7.7	12.0	16.5	13.5	34.5

*(significant), **(highly significant) & ns(non significant) at p=0.05. Treatment means bearing same letter are not significant different at p=0.05 by DMRT. SEM=Standard Error of Mean, LSD=Least Significant Difference & CV=Coefficient of Variance, SPAD=Spad Reading, NKRPE=Number of Kernel Row / Ear, NKPR=Number of Kernel / Row, EW=Ear Weight, FHKW=Five Hundred Kernel Weight, GYPP=Grain Yield / Plant, GYPH=Grain Yield / Hectare.

Table 2: Estimation of genetic parameters (GAM, PCV and GCV) for fourteen maize genotypes in Chitwan, Nepal, 2014/15

Variable	GCV	PCV	h_{bs}^{2}	GAM
SPAD	2.519	7.332	0.118	1.783
NKRPE	5.941	9.688	0.376	7.506
NKPR	8.7	14.831	0.344	10.513
EW	14.922	22.255	0.45	20.612
FHKW	3.43	13.977	0.06	1.734
GYPH	49.193	60.106	0.67	82.939

Vg=genotypic variance, Ve=environmental variance, Vp=phenotypic variance, GCV=genotypic coefficient of variation, PCV=phenotypic coefficient of variation, GAM=genetic advance as percentage of mean, h_{bs}^{2}=broad sense heritability, SPAD=Spad reading, NKRPE=number of kernel row/ear, NKPR=number of kernel/row, EW= Ear Weight, FHKW= Five hundred kernel weights, GYPH= grain yield/ha

Table3. Pearson’s correlation coefficient between yield and yield attributing traits of fourteen genotypes of maize in Chitwan, Nepal, 2014/15

	SPAD	NKRE	NKPR	EW	FKW	GYPH
SPAD	1.00					
NKRE	0.45^{**}	1.00				
NKPR	0.31^{*}	0.53^{**}	1.00			
EW	0.51^{**}	0.58^{**}	0.74^{**}	1.00		
FKW	0.04^{ns}	-0.11^{ns}	-0.07^{ns}	0.40^{**}	1.00	
GYPH	0.31^{*}	0.39^{**}	0.59^{**}	0.78^{**}	0.35^{*}	1.00

PAD= Spad reading, NKRPE=number of kernel row/ear, NKPR=number of kernel/row, EW= Ear Weight, FHKW= Five hundred kernel weights, GYPH= grain yield/ha

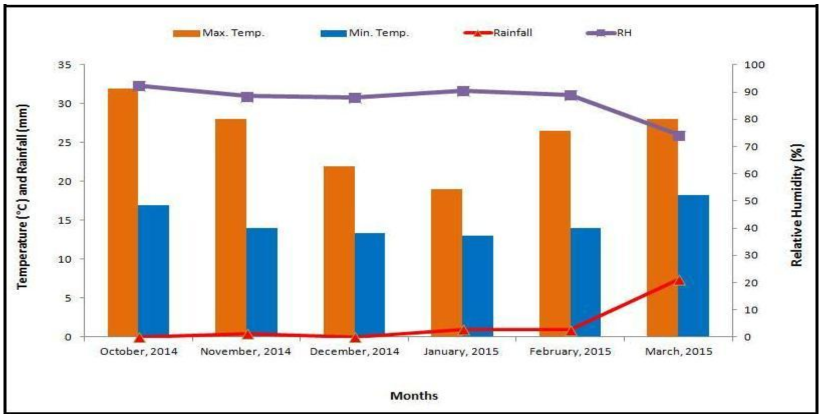


Figure1: Meteorological data during the growing period of Maize at Rampur Chitwan 2014/15

Chart of GYPH vs GENOTYPES

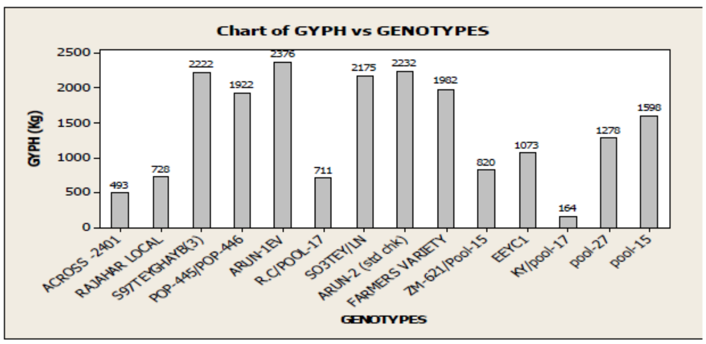


Figure 2: Genotypes with their yields (kg/ha)

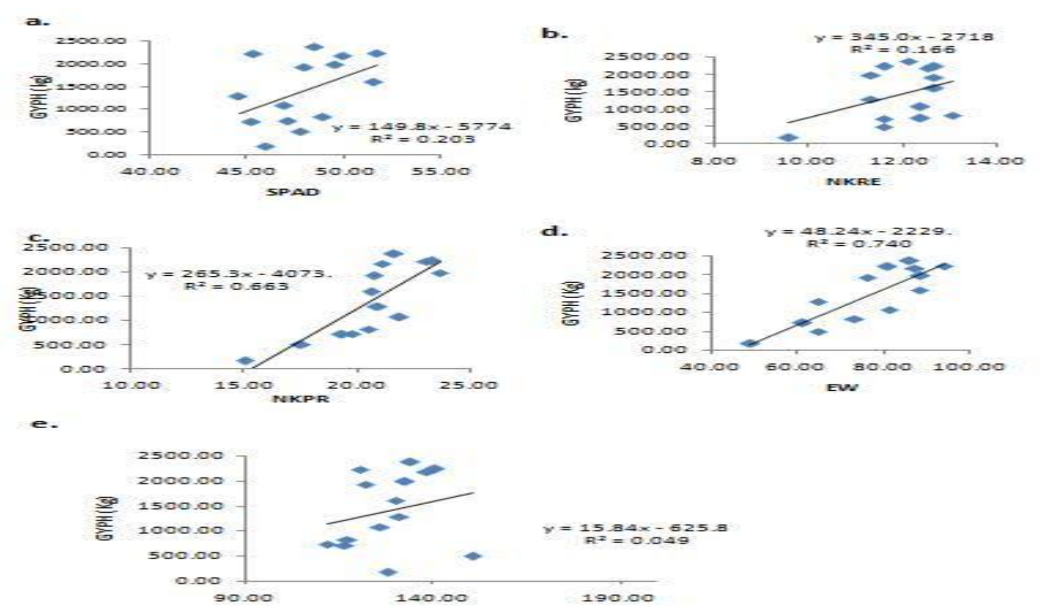


Figure 3. Estimated liner correlation (a) between SPAD reading and grain yield/ha (GYPH), (b) between NKRE (number of kernel row/ear) and grain yield/ha (GYPH), (c) between NKPR (number of kernel/row) and grain yield/ha (GYPH), (d) between EW (ear weight) and grain yield/ha (GYPH), (e) between FHKW (five hundred kernel weight) and grain yield/ha (GYPH)

REFERENCES

Afzal, S., Vannirajan, C., & Arumigachamy, S. (2005). Genetic Variability Studies in Maize Germplasm. *Plant Archives , 5* (1), 105-108.

Ajmal, S. U., Sohail, K., Saleem, M., & Haq, M. I. (2000). Association analysis for grain yield and yield components in maize. *Pak. J. Pl. Sci. , 6*, 12-17.

Alvi, M. B., Rafique, M., Shafique, M., Hussain, A., Mohommad, T., & Sarwar, M. (2003). Characters Association and Path Analysis of Grain Yield and Yield Components in Maize. *Pakistan Journal of Biological Science , 6* (2), 136-138.

Araus, J. L., Slafer, G. A., Royo, C., & Serret, M. D. (2008). Breeding for yield potetal and stress adaptation in cereals. *Critical Reviews in Plant Sciences , 27* (6), 377-412.

Burton, G. W., & Devane, E. M. (2008). Breeding for yeild potential and stress adaptation in cereals. *Critical Reviews in Plant Sciences , 27* (6), 377-412.

Chaudhary, L. B., & Prasad, B. (1968). Genetic variation and heritablity of quantitative characters in Indian mustard (Brassica Juncea). *Indian Journal of Agricultural Science , 38*, 820-825.

Gitelson, A. A., Vina, A., Masek, J. G., Verma, S. B., & Suyker, A. E. (2008). Synoptic monitoring of gross primary productivity of maize using Landsat data. *5*, 133-137.

Grafius, J. E. (1959). Heterosis in Barley. *Agronomy Journal , 51*, 551-554.

Grzesiak, S. (2001). Genotypic variation between maize (Zea mays L.) single-cross hybrids in response to drought stress. *Act a Physiologiae Plantarum , 23* (4), 443-456.

Hallauer, A. R., & Miranda, J. B. (1988). *Quantitative Genetics in Maize Breeding* (2nd ed.). Iowa, Ames. USA: Iowa State University Press.

Hanson, G. H., Robinson, H. F., & Comstock, R. E. (1956). Biometrical studies of yield in segregating populations of Korean hespedeza. *Agronomy Journal , 48*, 267-282.

Hanson, G. H., Robinson, H. F., & Cornstock, R. E. (1956). Biometrical studies of yield in segregating populations of Korean hespedeza. *Agronomy Journal , 48*, 267-282.

Ibitome, J. D. (2010). Heterosis and combining ability studies for yield components traits using diallel analysis among ten inbred lines of maize (*Zea mays* L.).

Ihsan, H., Khalil, I. H., Rehman, H., & Iqbal, M. (2005). Genotypic Variability for morphological traits among exotic maize hybrids. *Sarhad J. Agric. , 21* (4), 599-602.

Johnson, H. W., Robinson, H. F., & Cornstock, R. E. (1955). Estimates of environmental variability in Soyabeans. *Agronomy Journal , 47*, 314-318.

Kumar, P. G., Prashanth, Y., Kumar, S. S., Reddy, N. V., & Rao, V. P. (2014). Character association and path coefficient analysis in maize (*Zea mays* L.). *International Journal of Applied Biology and Pharmaceutical Technology* .

Kumar, S., Reddy, M. T., Reddy, K. H., & Sudhakar, P. (2011). Targeting of traits through assessment of interrelationship and path analysis between yield and yield components for Grain Yield Improvement in single cross hybrids of maize (*Zea mays* L.). *International journal of applied biology and pharmaceutical technology , 3* (2), 123-129.

Kumar, S., Shahi, J. P., Singh, J., & Singh, S. P. (2006). Correlation and path analysis in early generation inbreds ofmaize (*Zea mays* L.). *Crop Improvement , 33* (2), 156-160.

Lee, M., & Lamkey, K. R. (2006). The phenotypic and genotypic eras of plant breeding In. *The Arnel R. Hallauer International Symposium* (pp. 213-218). Ilowa, USA: Blackwell Publishing.

Lush, J. L. (1940). Inter-size correlation regression of offspring on dairy as a method of estimating heritability of characters. *Proceedings American Soceity of Animal Production , 33*, 293-301.

MoAD. (2014). *Statistical Information on Nepalese Agriculture 2013/14.* Singa Durbar, Kathmandu Nepal: Ministry of Agriculture and Development, Agri-Business Promotion and Statistics Division.

Rafique, M., Haussain, A., Mahmood, T., Alvi, A. W., & Alvi, M. B. (2004). Heritability and interrelationships among grain yield and yield components in maize (*Zea mays* L.). *Int'l. J. Agric. & Biol , 6* (6), 1113-1114.

Robinson, H. F., Comstock, R. E., & Harvey, P. H. (1949). Estimates of heritability and degree of dominance in corn. *Agronomy Journal , 41*, 353-359.

Robinson, H. F., Cornstock, R. E., & Harvey, P. H. (1949). Estimates of heritability and degree of dominance in corn. *Agronomy Journal , 41*, 353-359.

Sivasubramanjan, S., & Menon, M. (1973). Heterosis and inbreeding depression in rice. *Advances in Agronomy , 47*, 85-140.

Venugopal, M., Ansari, M. A., & Rajanikanth, T. (2003). Correlation and path analysis in maize. *Crop Research Hissar , 25* (3), 525-529.

Viola, G., M, G., Reddy, S. S., & Kumar, C. V. (2004). Study on heritability and genetic advances in elite baby corn (*Zea mays* L.) lines. *Progressive Agriculture , 3* (2), 127-128.

Webber, C. R., & Moorthy, B. R. (1952). Heritable and non-heritable relationship and variablity of oil content and agronomic characteristics in the F generation of soybean crosses. *Journal of Agronomy , 44*, 202-209.

Welsh, J. (1981). *Fundamentals of Plant Breeding and Genetics.* New York: Jhon Weliey & Sons.

Yousuf, M., Ajmal, S. U., Munir, M., & Ghafoor, A. (2011). Genetic diversity analysis for agromorphological and seed quality traits in rapesees (*Brassica campestric* L.). *Pak. J. Bot. , 43* (2), 1195-1203.

Journal of Maize Research and Development (2015) 1(1):146-152
ISSN: 2467-9305 (Online)/ 2467-9291 (Print)
DOI: 10.5281/zenodo.34265

Technology adoption analysis of improved maize technology in western hills of Nepal

Jeevan Lamichhane[1*], Krishna P. Timsina[2], Durga B. RanaBhat[1] and Surya Adhikari[1]

ARTICLE INFO

Article history:
Received:
11th August, 2015 Revised:
15th September, 2015 Accepted:
19th October, 2015

Keywords:
Maize, adoption, improved variety, respondents

ABSTRACT

The survey was carried out in t wo districts namely Palpa and Bag lung to determine the current level of adoption of improved maize production practices. This study identifies the technology adoption extent and pattern of imp roved maize technologies in Western Hills of Nepal. In each of these districts, two village development committees (V.D.Cs) were surveyed. Deurali and Khasyouli V.D.C fro m Palpa and Kudule and Malika V.D.C fro m Baglung Districts were selected. Structured Questionnaire were admin istered to 30 randomly selected households in each VDC. Altogether 120 Households were surveyed. The degree of adoption was measured on the seed rate, adoption of improved varieties, application of Nitrogenous, Phosphatic and Potassium fertilizer, Weeding and method of planting. The adoption index was used to determine the adoption level of the respondents. There seems to be a gap between the recommended practice and current level of practice at the farmers level in some of the factors like Nitrogenous, Phosphorus and Potassium fertilizers, method of planting .The study revealed that majority farmers belonged to high adoption category (57%) followed by mediu m adoption category(54%) and low adoption category (9%). The Technology Adoption Index (TAI) was found 63% . In nutshell there is still large scope for yield improvement of the maize in the study area by adopting improved maize variet ies.

INTRODUCTION

In Nepal, maize (*Zea mays* L.) is the second most staple food crops, while in hills it is a principal food crop. Maize is the most important cereal crop in the hills of Nepal, where the grain is used for human consumption and the Stover for animal fodder. It is usually used for food, feed, fodder, and fuel and is a significant source of energy (Adhikari, 2008). Maize cultivation is a way of life for most farmers in the hills of Nepal. It is grown under rainfed conditions during the summer (April- August) as a single crop or relayed with millet later in the season. More than two thirds of the maize produced in the mid hills and high hills is used for direct human consumption at the farm level and the ratio of human consumption to total

Corresponding author Info:
1Regional Agricultural Research Station (RARS), Lumle, Kaski, Nepal
2Nepal Agricultural Research Council (NARC), Singhadurbar Plaza, Kathmandu, Nepal
Contact No : 9845090840
**Email: jeevanlamichhane7@gmail.com , Scientist(S-1)*

production is higher in less accessible areas (Paudel, 2008). Area under this crop is approximately 9,28,761 ha which is about 28% of total cultivated area . Total production of maize in 2013/14 is 22,83,222 metric tons (MoAD, 2014). Only about 16% of Nepal's total land area is cultivated. Of this, the terai, where 38% of the land area is cultivated, is the most important. Maize is the third most important crop here after paddy and wheat. The second most important agricultural land area is the mid hills where 15% of land is cultivated. Of the total maize area about 78% falls in the hills Area (mid Hills 70%, and high hills 8%). Maize is generally grown under rain- fed condition in Nepal with basal application of low quantity of Farm yard manure. Unavailability of quality seed of farmer's preferred varieties at right time, in desired quantities and at reasonable price is the major constraint for increasing production (Adhikari *et al*., 2003). Most of the farmer keep their own seeds year after year. More than 88% farmers used farm saved seeds (Gurung, 2011). Maize yields fluctuate seasonally and annually especially in the hills. Although maize yields increased slightly over the past five years, there has been very little yield improvement when compared to nationwide yield 30 years ago. This is probably due to the expansion of maize cultivation into less suitable terrain, declining soil fertility, and the adoption of improved management practices. While productivity in the country is almost stagnant, the overall demand for maize driven by increased demand for human consumption and livestock feed is expected to grow by 4% to 6 % per year over the next 20 years. Thus, Nepal will have to resort to maize imports in the future if productivity is not increased substantially. National average yield of maize is 2.5 t/ha. Seed replacement rate in Maize is about 11.3% (Pokharel, 2013). This study has taken seven main cultivation practices like Improved varieties, Seed rate, Nitrogenous fertilizer, Phosphatic fertilizer, Potassium fertilizer, Planting method, Weeding into consideration and have tried to find out the technology adoption level of these factors in Western Hills of Nepal. Where maize is grown, farmers often do not apply adequate amounts of fertilizer. Even when applied, the basal application, which is crucial from the production point of view, is missed. Application of fertilizers is very important for increasing the productivity (Tiffen, 2003). A research conducted by Sharma in 1980 showed that row planting produce the highest maize yield. The maize yield of different maize varieties respond positively to seed rate (Pinter *et al*., 1994). Recommended seed rates rates usually results in increases maize yield (Lucas, 1986). Generally, the presence of weeds for the first six, nine and twelve weeks after sowing and for the entire growing season of maize resulted in estimated yield losses of 36, 61, 80, and 85%, respectively (Assefa,1999). The technology adoption index is a catch-all measure of technology practices of the farmers (Singh *et al.,* 2005 cited in Timsina *et al.,* 2012). Technology Adoption index measures the adoption level of the number of practices of any technology. Very few study have been done concerning the Technology Adoption index in the past which were confined to Rice production technology in terai region. This study tries to explore the adoption level of improved maize technology in Western Hills of Nepal.

MATERIALS AND METHODS

The study was conducted in two districts namely Baglung and Palpa. Respondents were chosen from both the Outreach site (O.R sites) and Non Outreach sites (Non O.R sites). Deurali V.D.C (O.R site) and Khasyouli V.D.C (Non O.R site) from Palpa, Kudule(OR site) and Malika V.D.C(Non OR site) from Baglung Districts were chosen for sample selection. From each V.D.C

30 respondents were selected randomly using Simple Random sampling among the farmers cultivating maize for at least the previous two years. Therefore, the total sample size for the study was 120. For studying the extent of adoption 7 important cultivation practices i.e. improved varieties, seed rate, and application of nitrogenous, phosphatic and Potassium fertilizers, Weeding and planting method were considered. The recommended dose of Nitrogenous, Phosphorus and Potassium fertilizer for Maize is 104.9, 65.22 and 50 kg per hectare respectively. Recommended number of Weeding is 2. Recommended seed rate is 20 kg/hectare. Recommended method of sowing is line sowing. Different techniques such as interview, group discussions and informal Discussions with farmers were used for the study. The analysis was based on tabular analysis using simple statistical methods like frequency, mean and standard deviation. However to know the adoption pattern of improved technologies the adoption index was calculated. The technology adoption index (TAI) was calculated by using formulae given by Singh *et al.*, 2005 cited in Timilsina *et al.*, 2012).

$$TAIi= 1/7(AHi/Cai+ Sai/Sri+Nai/Nri+Pai/Pri+Kai/Kri+Wai/Wri+Rai/Rri)$$

where i= Numbers of farmers say 1,2,3…………….n,

Tai = Technology Aoption index of ith farmer

Ahi= Area under improved maize varieties (ha)

Cai= Total Area under improved Maize varieties

Sai=Quantity of seed applied per hectare   Sri= Recommended seed Rate

Nai= Quantitiy of Nitrogen applied per ha,   Nri= Recommended dose of Nitrogen per ha

Pai = Quantitiy of Phosphorus applied per ha,   Pri = Recommended dose of Nitrogen per ha,

Kai= Quantitiy of Potassium applied per ha,   Kri= Recommended dose of Potassium per ha

Wai=Number of Weeding applied   Wri= Recommended Number of Weeding

Rai= Method of sowing,   Rri= Recommended method of sowing

Depending upon the extent of adoption of improved technologies the respondents will be categorized as:

Low adopters (LA)   from 0-33 per cent,

Partial adopters (PA)   from 34 – 66 per cent, and

High adopters (HA)   from 67 – 100 per cent.

RESULTS AND DISCUSSION

Demographic Characteristics

Table 1 summarizes Demographic characteristics of sample farmers in the Study Area. The mean age of household head in Baglung and Palpa was 55 and 48 yrs respectively. The average size of the family in Baglung and Palpa was 5 &4 respectively. Majority of the household was male headed households. Most of the households belong to Brahmin and Kshetri, Ethinicity. The average size of the lowland was 4.54 ropani in Baglung and 4.25 ropani in Palpa. Likewise the average size of upland was found to be 4.35 ropani in Baglung and 4.53 ropani in Palpa. The educational experience of the household heads in Baglung and Palpa Districts was about 4.3 and 3.4 years respectively.

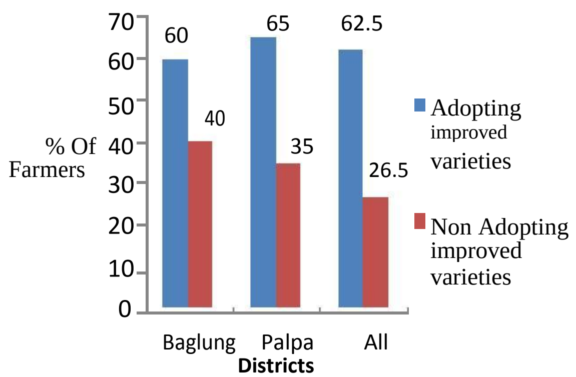
Pattern and extent of improved Varieties Adoption

The nature and extent of the modern variety adoption in the field is a good measure of the crop research program. Adoption of crop varieties are generally by two indicators: the proportion of farmers growing modern varieties and the proportion of area under improved varieties. Fig 1 describes the percentage of farmers adopting the improved varieties. The percentage of farmers adopting improved maize varieties was 60% in Baglung whereas it was 65% in Palpa . Overall percentage of the farmers adopting the improved maize varieties is 62.5 %. Fig 2 explains the percentage of area coverage by the improved varieties. Of the total maize growing area in the study sites 61% of the area is covered by improved varieties in Baglung Districts and it is 64% in Palpa District. The most popular improved varieties mainly adopted by farmers in the survey sites are Rampur Composite (40%), ManaKamana6 (40%) & Arun2 (20%).The main reason for adopting these varieties was because they were less prone to lodging, has good taste and these varieties have higher yield compared to the local one. Despite of the adoption of the variety there were some varieties that were disadopted. The varieties disadopted were Manakamana 1, Manakamana 5. These varieties were disadopted because they were prone to lodging and succeptible to disease and pests.

Table 1: Demographic Characteristics of the study sites

Socioeconomic characters	Baglung	Palpa
Age of the Household head	55	48
Family Size	5	4
Male headed Household	42	32
Female headed Household	18	28
Ethnicity(number)		
Brahmin/Kshetri	51	50
Janjati	9	1
Dalit	0	9
Lowland (ropani)	4.54	4.25
Upland (ropani)	4.35	4.53
Education(yrs)	4.3	3.4

*1 ha = 20 ropani



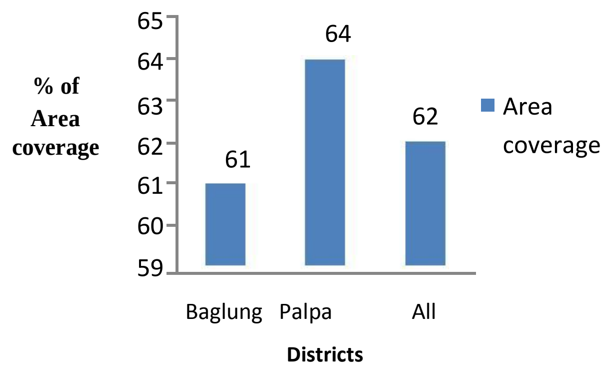


Fig 1: percentage of the farmers adopting improved variet ies Fig 2 : percentage of Area coverage by improved varieties

Technology Adoption Analysis of Improved Maize technology

The responses received from the respondents were categorized as low (up to 33.33 %), medium (33.34 to 66.66 %) and high adoption (above 66.66 %). Table 2 presents the current level of practice of the different factors at the study sites taken into consideration. Average Seed rate in Palpa is 40 kg/ha whereas in Baglung it is 49 kg/ha. Average use of Nitro genous, Phosphorus and Potassium fertilizer in palpa is 45,11 and 10 kg/ha respectively whereas in Baglung it is found to be 75,10 and 12 kg/ha respectively. Both the districts are following the recommended number of weeding. Row planting is not followed b y any farmers in both the districts. Practice wise category of adoption of improved maize production technology is presented in Table 3.

With regards to recommended seed rate all respondents in both the District were observed to be high adoption category. Suwar (1981) also found respondents to be in high adoption category regarding adoption of seed rate in . With regards to nitrogenous fertilizers, majority of the farmers in Palpa were from low adoption category whereas in Baglung majority of the respondents were from high adoption category. With regards to phosphatic and Potassium fertilizers all the respondents were from low adoption category. Govereh *et.al*, (2003) in Zambia also found the adoption of Nitrogenous fertilizers to be in high adoption catego ry compared to other chemical fertilizers. None of the farmers were found to practice row planting in both Districts. Ephraim and Featherstone (2001) also found that only 1 % of the total sampled respondents followed the row planting in Tanzania. Data presented in table 4 indicates that majority of respondents were found in high adoption category followed by medium adoption category and low adoption category. Etoundi and Dia (2008) report also found 70% of the respondents to be in high adoption category in adopting Maize improved technology in Cameroon. Low adoption of improved technology is due to non-availability of improved varieties seed at proper time and lack of knowledge. The technology Adoption index in Palpa and Baglung is 61% and 65% respectively.

Table 2: Recommended practice and current level practice of different factors taken into consideration at the study sites

practices	Palpa		Baglung	
	Recommended practice	Current practice	Recommended practice	current practice
Seed rate	20 kg/ha	40 kg /ha	20 kg/ha	49 kg/ha
Nitrogenous Fertilizer	104.9kg/ha	45kg/ha	104.9kg/ha	75kg/ha
Phosphorus Fertilizer	65.22kg/ha	11kg/ha	65.22kg/ha	10 kg /ha
Potassium Fertilzer	50kg/ha	10kg/ha	50 kg/ha	12 kg/ha
Number of Weeding	2	2	2	2
Planting method	row planting	sowing after plough	row planting	sowing after plough

Table 3: Frequency and percentage of farmers with different cultivation practices

Cult ivation Practices	Palpa			Baglung		
	low adopter	med iu m adopter	high adopter	low adopter	med iu m adopter	high adopter
Improved varieties	10(17)	20(33)	30(50)	6(10)	24(40)	30(50)
Seed rate	0	0	60(100)	9(15)	0	51(85)
Nitrogen	38(62)	5(8)	17(30)	6(10)	12(20)	42(70)
Phosphorus	60(100)	0	0	60(100)	0	0
Potassium	60(100)	0	0	60(100)	0	0
Weeding	0	5(8)	55(92)	3(5)	0	57(95)
Row planting	60(100)	0	0	60(100)	0	0

Figure in the parenthesis indicates percentage

Table4 : Frequency and percentage of farmers with different categ ories of adoption in the study sites

Category	Palpa	Baglung	Total
Low adopter(0-33%)	3(5)	6(10)	9(8)
Medium adopter (33-66%)	37(62)	17(29)	54(45)
High adopter (67-100%)	20(33)	37(61)	57(47)
Overall TAI(%)	61	65	63
Total	60	60	120

Figure in the parenthesis indicates percentage

CONCLUSION

From the study it is revealed that area covered by the improved varieties of Maize was found to be 62% in the study area. It can be concluded that majority of the farmers belonged to high adoption category. Still most of the farmers have been using the different local varieties. The improved varieties like Rampur Composite, Manakamana 6, Arun 2 are popular in the study districts. The contribution of Seed rate in Technology Adoption index was found to be higher followed by Varieties and Nitrogenous fertilizer. There is a greater scope of increasing Technology Adoption index by increasing use of phosphorus, potassium fertilizers and high yielding varieties following row planting method. Also if the rainfed farming can be replaced with irrigation, adoption index can be increased. The study suggests that the practices of applying Nitrogenous, phosphorus, potassium fertilizers, method of planting, which had low adoption by farmers should give due attention by extension agencies, so that the existing level of adoption of such practices can be increased. Efforts should be made to increase the extension contacts of the farmers with extension workers to increase their level of adoption. It can be concluded that despite of the rainfed condition yield of the maize can be increased by using improved varieties, recommended use of Nitrogenous, Phosphorus and potassium fertilizers, seed rate, planting method, weeding.

ACKNOWLEDGEMENTS

Authors want to thank Nepal Agricultural Research Council for providing fund to carry out this study. Authors want to extend sincere gratitude to the respondents of Baglung and Palpa Districts for their valuable help. Authors want to thank District Agriculture Development Office Baglung and Palpa for their help.

REFERENCES

Adhikari, K., Ransom J.K., & Paudyal, K. (2003). Adoption of improved maize varieties in the hills of Nepal. *Journal of the International Association of Agricultural Economics* 29(3), 299-305.

Adhikari, K.P. (2008). Effectiveness of integrated pest management technology through Farmers Field School on vegetable production in Nawalparasi and Kavre district of Nepal.Thesis,M.Sc. Institute of Agriculture and Animal science, Rampur, Chitwan, Nepal. pp . 29-44.

Assefa,T. (1999). Weed incidence and control in the major crops at Assosa. An overview. In: Fasil Reda and D.G. Tanner (eds.). *Arem,* 5,14-26

Ephraim, M., & Featherstone, A.M . (2001) Crosspollinated crop variety adoption studies and seed recycling: the case of maize in Tanzania. *Eastern African Journal of Rural Development* ,17(1), 25-34.

Etoundi, S.M.N., & Dia, B.K. (2008). Determinants of the adoption of improved varieties of Maize in Cameroon: case of CMS 8704. *Proceedings of the African Economic Conference*. pp. 397-413.

Govereh, J., Jayne, T.S., Sokotela, S., & Lungu, O.I. (2003). Raising maize productivity of smallholder farmers in Zambia: what can fertilizer consumption alone do or not do?

Gurung, K, (2011). Impact Assessment of HMRP J.Agril.Eco.30, pp308-312 *Income Growth. World Development*, 31(8), 1343-1366.

Lucas, E.O. (1986). The effect of density and nitrogen fertilizer on the growth and yield of maize (Zea mays L.) in Nigeria. *J. Agric Sci. Camb*., 107, 573-78.

MoAD. (2014). Statistical information on Nepalese Agriculture . Ministry of Agriculture and Cooperatives. Government of Nepal. Kathmandu, Nepal. pp164-165.

Navaya, J.L., & Gurung, D.B. (2010). Impact of climate change on production and productivity: A case study of maize research and development in Nepal. *The Journal of Agriculture and Environment* , 11, 35-38.

Paudel, P. (2008). Factors influencing of improved maize varieties in Nepal: A case study of Chitwan district. *Australian Journal of Basic and Applied Sciences*, 2(4), 823-834.

Pinter, L., Elfoldi, Z., Burues, Z., & Paldi, E. (1994). Feed value of forage maize hybrids varying in tolerance to plant density. *Agronomy Journal*, 86, 799-804.

Pokhrel, T. (2013). Impact of Maize varieties Disseminated in Chitwan, Nepal. *Economic Journal of Nepal*, 42 (6), 45-53.

Singh, R.P., Kumar, R., & Singh, N.P. (2005). Identification of pulling Factors for Enhancing the Sustainable Develpoment of Agricultural with Special Reference to Maize in India. CAPSA Working paper No88.United Nations,ESCAP.

Suwar, A. (1981) effect of seed rates, sowing methods and fertilization on the performance of forage sorghum (*Sorghum bicolor* (L) Moench) grown on saline-sodic soil M. Sc. thesis, Faculty of Agriculture University of Khartoum.

Tiffen, M, (2003). Transition in Sub-Saharan Africa: Agriculture, Urbanization and Working Paper. Food Security Research Project, Lusaka, Zambia

Timsina, K.P., Bista, H.B., Gauchan, D., Sapkota, B., Ghimire, Y.N., Shrestha, K.P., & Shrestha, B. (2012). Adoption Analysis of Rice Varieties in Terai of Nepal. In the proceeding of 10th National Outreach Research Workshop held at Regional Agricultural Research Station, Lumle, from February 27-28, 2012. Published by Nepal Agricultural Research Council (NARC) & Outreach Research Division (ORD), Khumaltar, Nepal.